REPORT RESUMES

ED 011 516 SE 001 723

SUPERVISION FOR QUALITY EDUCATION IN SCIENCE, REPORT ON A CONFERENCE ARRANGED BY THE SPECIALISTS FOR SECONDARY SCIENCE (JUNE 25-29, 1962).
BY- ALEXANDER, UHLMAN S.
OFFICE OF EDUCATION, WASHINGTON, D.C.
REPORT NUMBER OE-29039-BULL-1963-NO-3 PUB DATE 63

EDRS PRICE MF-$0.27. HC NOT AVAILABLE FROM EDRS. 178P.

DESCRIPTORS- *CONFERENCE REPORTS, *NATURAL SCIENCES, *SCIENCE EDUCATION, *SUPERVISION, *SCIENCE SUPERVISION, CURRICULUM DEVELOPMENT, EDUCATIONAL OBJECTIVES, SECONDARY SCHOOL SCIENCE, DISTRICT OF COLUMBIA

SPEECHES AND REPORTS FROM A U.S. OFFICE OF EDUCATION CONFERENCE FOR STATE DEPARTMENT OF EDUCATION SCIENCE SUPERVISORS CONSTITUTE THIS BOOKLET. THE CONTENT IS DIVIDED INTO THREE MAJOR SECTIONS WITH SEVERAL SPEECHES OR REPORTS IN EACH. SECTION 1, "EDUCATION IN AN AGE OF SCIENCE," CONSISTS OF THREE PRESENTATIONS CONCERNED WITH SUCH TOPICS AS THE QUALITY OF AMERICAN EDUCATION, MANPOWER NEEDS IN OUR CULTURE, AND REQUISITES FOR A SCIENCE PROGRAM. SECTION 2, "SCIENCE IN THE CURRICULUM," IS COMPRISED OF EIGHT REPORTS, TWO REPORTS EACH ON EARTH SCIENCE, BIOLOGY, CHEMISTRY, AND PHYSICS. THE FIRST REPORT ON EACH OF THE FOUR SUBJECT AREAS RELATES TO THE MAJOR FORCES IMPINGING UPON THE PARTICULAR SCIENCE AND THE TEACHING OF THAT SCIENCE AND THE SECOND REPORT FOR EACH SUBJECT AREA RELATES TO MATERIALS AND TEACHING RESOURCES. IN THE FINAL SECTION, "SUPERVISION FOR THE IMPROVEMENT OF SCIENCE INSTRUCTION," SEVERAL PAPERS ARE PRESENTED ON THE GOALS OF SCIENCE EDUCATION AND DESIRABLE CHANGES IN TEACHING PRACTICES. INCLUDED IN THIS SECTION ARE BRIEF REPORTS OF CURRICULAR ACTIVITIES IN FLORIDA, GEORGIA, MISSOURI, AND PENNSYLVANIA. THIS BOOKLET IS AVAILABLE AS FS 5.229--29039 FROM THE SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402, FOR $0.65. (RS)

ED011516

OE-29039

Supervision for Quality Education in SCIENCE

SE 001 723

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Office of Education

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

OE-29039
Bulletin 1963
Number 3

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL OFFICE OF EDUCATION POSITION OR POLICY.

Supervision for Quality Education in SCIENCE

Report of a Conference
Arranged by the Specialists for
Secondary Science
June 25–29, 1962

Prepared by
UHLMAN S. ALEXANDER
Research Assistant for Science

U.S. Department of
Health, Education, and Welfare

Office of Education

Superintendent of Documents Catalog No. FS 5.229:29039

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 - Price 65 cents

Foreword

TO PROVIDE State supervisors of science with the opportunity to meet and discuss the various problems and responsiblities of their positions, the U.S. Office of Education sponsored a conference in Washington, D.C., during the week of June 25–29, 1962, on "Supervision for Quality Education in Science."

There were four primary objectives for the conference:

1. To review the latest developments in science important to education.
2. To explore new emphases in selected special fields of science teaching.
3. To exchange ideas related to new programs.
4. To develop guidelines for leadership in supervision of science.

The planning committee for the conference was comprised of the following personnel from the Office: J. Dan Hull, Ellsworth S. Obourn, Paul E. Blackwood, Richard M. Harbeck, Lloyd K. Johnson, Margaret J. McKibben, Albert Piltz, and A. Neal Shedd.

This report has been prepared from materials presented at the conference.

J. DAN HULL
Director,
Instructional Programs Branch

ERIC R. BABER
Assistant Commissioner,
Division of Elementary and Secondary Education

PRECEDING PAGE BLANK NOT FILMED

Contents

Page

FOREWORD III

HIGHLIGHTS OF THE PAPERS 1

THE PAPERS

I. Education in an Age of Science

Quality of Education, *by Bowen C. Dees* 12

Science and Education Today, *by M. H. Trytten* 20

Implications for Science Education, *by J. Darrell Barnard* 31

II. Science in the Curriculum

Earth Science in the Curriculum, *by Robert C. Stephenson* 43

Materials for Teaching Earth Science, *by Donald B. Stone* 52

Revolution in Biology, *by H. Bentley Glass* 57

Newer Resources for Improving Instruction in Biology, *by Paul Klinge* 68

Generalized Values of High School Chemistry, *by Zaboj V. Harvalik* 80

Newer Resources for Improving Instruction in Chemistry, *by Robert L. Silber* 86

Introducing Newer Concepts of Physics, *by Herman R. Branson* 95

Newer Resources for Improving Instruction in Physics, *by Ralph W. Lefler* 99

III. Supervision for the Improvement of Science Instruction

Emerging Problems of Supervision in Science, *by John H. Woodburn* 110

Emerging Curriculum Studies in Elementary and Junior High School Science, *by Philip G. Johnson* 122

New Programs in Science Youth Activities, *by A. Neal Shedd* 141

Page

III. Supervision for the Improvement of Science Instruction—Continued

REPORTS FROM FOUR STATES:

Emerging Programs in the Improvement of Science Education in Florida, *by Robert D. Binger* 147

The Georgia Program in Science Curriculum Revision, *by H. Victor Bullock* 151

Missouri's Inservice Science Workshop Program, *by John B. Leake* 154

The Pennsylvania Science Program, *by Albert F. Eiss* 157

Appendixes

A. Guidelines for the State Supervisor of Science 163

B. Participants in the Conference 168

Highlights
of the Papers

PRECEDING PAGE BLANK- NOT FILMED

Quality of Education

Bowen C. Dees

1. The quality of education in our best schools and colleges is high by any standard. Our outstanding graduate schools are probably the world's best.

2. Automation in commerce, industry, and Government will bring with it requirements for workers who have had more education of higher quality.

3. In striving to achieve higher quality, our schools will need to assess and reassess continuously the relative emphasis they give to the various components of their multiple task.

4. The most important element in any school is the quality of the teaching.

5. Research designed to lead to a further understanding of how children learn has unfortunately not been pushed as hard as it might and should have been.

6. All elements of our organized society can and should contribute to the massive task we face in trying to reach the American goal of equal and full educational opportunity for all.

Science and Education Today

M. H. Trytten

1. Science and technology have developed in four eras:
    - the era of "sporadic discovery" prior to the 17th century;
    - the era of the enlightenment, signalized by Bacon, Newton, Leibnitz, and Galileo;
    - the era of practical applications of science; and
    - the era of Government interest in the acceleration of science.

2. There is an increasing national need for greater numbers of scientific and engineering personnel.

3. Our present rate of training in scientific and engineering areas is inadequate to meet the growing need.

4. Probably first among all the goals for science teaching is that of science for the citizen.

5. Among our greatest unused potentials for scientific personnel are women and graduates of small high schools.

Implications for Science Education

J. Darrell Barnard

1. Construction of a sound science curriculum is dependent upon the development of meaningful objectives for science education.

2. A good science program results in an understanding of both the concepts and the processes of science.

3. It is imperative that science education provide citizen graduates with both the motivation and the skills to continue their intellectual development.

4. Science improvement projects have recently made worthy breakthroughs in the field of science education, but three areas of concern should be noted: their exclusive commitment to basic science, the extent to which they are adaptable to all students, and how they can be incorporated into a K to 12 sequence.

Earth Science in the Curriculum

Robert C. Stephenson

1. The study of earth science is now increasing throughout the Nation.

2. The earth sciences contribute greatly to the understanding of man's physical and biological environments.

3. Earth science subject matter can be introduced into the science program at all grade levels.

4. Teaching resources for the earth sciences are at present widely scattered.

5. Teacher training is probably the greatest problem facing the successful adoption of earth science into the science program.

Materials for Teaching Earth Science

Donald B. Stone

1. Aids for teaching earth science include samples of rocks and minerals, special maps, geologic models and weather equipment, as well as equipment usually found in any science department.
2. A course in earth science offers values from both practical and cultural points of view.

Revolution in Biology

H. Bentley Glass

1. Our fund of biological knowledge is increasing exponentially.
2. Current biology textbooks represent, for the most part, the biological knowledge of 30 years ago.
3. Our educational system is poorly organized to cope with the transmission of exponentially increasing knowledge. A thorough revision of the program of science teaching at all levels seems necessary.
4. Our main objective in science education is to learn and to teach the nature of science.

Newer Resources for Improving Instruction in Biology

Paul Klinge

1. Biological research breakthroughs have affected the teaching of biology in three ways: (*a*) less observation and more experimentation; (*b*) change in proportionate emphasis; and (*c*) increased need for understanding of chemistry and physics.
2. Certification patterns for biology teachers have been steadily changing throughout the country.
3. The Biological Sciences Curriculum Study is a most important resource for the improvement of instruction.
4. Other aids to the biology teacher include: reading resources, supply company aids, audiovisual aids, television, methodology textbooks, career pamphlets, professional societies, curriculum guides, and student programs.

5. Some of our most immediate needs are:
    - To revise the preservice training of biology teachers;
    - To increase the support given to biology teaching by various foundations;
    - To increase the interests professional organizations have in biology teaching;
    - To increase industry's support of biological science programs; and
    - To edit biology courses so as to teach the most important things.

Generalized Values of High School Chemistry

Zaboj V. Harvalik

Science and technology have important roles in the modern world. High school chemistry has the responsibility of preparing students for this world by transmitting to them such values as the processes of thinking, observing, and transferring.

Newer Resources for Improving Instruction in Chemistry

Robert L. Silber

1. Curriculum content studies (such as the Chemical Bond Approach Project and Chemical Education Materials Study) are having a major influence on the high school chemistry course.
2. Sources of information and aids for the chemistry teacher include professional journals, industrial films, paperback books, science kits, television, and programed instruction.
3. Attention to the high school chemistry laboratory is increasing.
4. The rapidly increasing frontiers of chemistry require that the chemistry teacher use every means available to keep his knowledge up to date.

Introducing Newer Concepts of Physics

Herman R. Branson

1. Training the student to repeat the classical laws of physics is inadequate preparation for an understanding of modern research in physics. An analysis of some early experiment, traced through to contemporary application, is more likely to be fruitful.
2. An understanding of recent developments in physics depends also upon an understanding of techniques, such as the production of vacuums, charged particles, and magnetic fields.
3. A basic goal of physics is the representation of all physical phenomena in a consistent schema with a minimum of concepts, hypotheses, principles, and laws.

Newer Resources for Improving Instruction in Physics

Ralph W. Lefler

1. The Physics Curriculum of the Physical Science Study Committee is an outgrowth of the rebellion of students and teachers to the stultifying effects of earlier forms of physics instruction.
2. The American Institute of Physics and the American Association of Physics Teachers are providing a wide variety of publications designed to improve the quality of physics instruction.
3. Projects sponsored by the AAPT and the AIP include the Regional Counselor Program, the Visiting Scientists Program in Physics, and a high school awards program.
4. Future curriculum programs in physics will—
    - ◆ Stress pure science as opposed to technology.
    - ◆ Emphasize laboratory work.
    - ◆ Demand more of both teachers and students.
    - ◆ Be based on continuing school-college cooperation.

Emerging Problems of Supervision in Science

John H. Woodburn

1. Too often the student brings to class the attitudes fostered by public criticisms of education, rather than the constructive attitudes educators should be developing in them.
2. Material inadequacies (buildings, equipment, supplies) add to the problem of good science teaching.
3. Science may well be taught as is art, with an emphasis on human endeavor and a close look at the environment which produces this endeavor.
4. There are many possible approaches to curriculum construction in science education. The most productive of these involves the student directly with science and its methods, rather than merely its external structure of facts and principles.
5. New knowledge is coming too fast for the teacher to be able to keep up with all of it. The excitement and spirit of science, however, remain constant, and it is these we must give to the student.

Emerging Curriculum Studies in Elementary and Junior High School Science

Philip G. Johnson

1. Much of what is emerging in curriculum studies today actually began several centuries ago.
2. The nature of our present curriculum materials for elementary and junior high school science must be recognized when plans are made for program improvement.
3. Newer studies include those of the Science Manpower Project, the Univeristy of California Project, the University of Illinois Project, the Educational Services Incorporated Project, and the American Association for the Advancement of Science Studies.
4. Currently emerging studies indicate the following changes can be expected in future elementary and junior high school science programs:
    - Less subject matter to be covered.
    - Attention to many relatively unstructured methods of inquiry.
    - The use of more references.
    - Greater emphasis on how to create knowledge.

- Development of greater skills of inquiry.
- Attention to concepts as they arise in the process of testing hypotheses.
- More and more stress on quantitative measurement.
- Orientation of science education as basic education for all students.
- Increased attention to the experimental nature of science.
- Recognition of more fundamental frames of reference than topics.
- Emphasis on science rather than technology.
- Development of more thorough application of mathematics to science.

New Programs in Science Youth Activities

A. Neal Shedd

1. In addition to formal classroom instruction, a program of class-related activities is needed to stimulate an interest in the student to whom science is new and to satisfy the student who has developed a deep interest and competency in science.

2. The U.S. Office of Education has devoted much time and effort to stimulating the growth of science clubs as an integral part of the secondary school program.

Reports From Four States

1. Recent science education programs in Florida include:
   (*a*) the *Physical Science Study Committee* course (PSSC);
   (*b*) the U.S. Office of Education Program *Science Teaching—Exploring for Excellence—Program Steps* (STEPS) in the Chipola Area; and
   (*c*) Institutes for the improvement of the junior high school science program.

2. Georgia has instituted a traveling science teacher program to provide State leadership for inservice training and work in classroom situations.

3. Inservice science workshop programs, especially at the elementary school level, have formed a major part of the science education program in Missouri. A second important development is the organization of evaluative workshops for a K to 12 science program.

4. Pennsylvania's science education program has placed primary emphasis on the development of a sequential curriculum, as illustrated by the *Science in Action* publication series.

The Papers

Although the U.S. Office of Education is responsible for editing the following papers, the conclusions and interpretations are those of the authors and do not necessarily represent the views of the Office.

I. Education in an Age of Science

Quality of Education

Bowen C. Dees

Assistant Director for Scientific Personnel and Education
National Science Foundation

I RECENTLY HEARD a distinguished international civil servant (not an American) say that the people of this country are not sufficiently arrogant; in part, at least, he was saying that we do not recognize the high overall quality of our educational system and its "product." Not long ago a well-known Swedish expert on education commented in my presence that he found it difficult to understand why Americans are so masochistic in their criticism of the U.S. school system.

I believe Henry Steele Commager was correct when he said: "No other people ever demanded so much of education as have the American; none other was ever served so well by its schools and educators."

Some Americans have been impressed in recent years with the rate at which the Russians are forging ahead in educational areas that seem to be of importance to the cold war effort, and they have therefore raised serious questions concerning the adequacy of the American way of handling educational problems.

Why are we so critical of our educational system? Are we not in fact justified in being proud of it? Should we revise it after the pattern of the British or the French or the German or the Russian systems?

In my view we are clearly ahead of the other countries of the world in education. Having said this, however, it is important to say at once that there are some components of other systems that are probably superior to the corresponding components of our system.

The American people are without doubt committed to an educational ideal unexcelled elsewhere in the world. We are critical of our achievements in education, as in many other areas of national concern, precisely because we know that our educational ideals have still not been fully achieved. We believe in equal educational opportunity for every boy and girl, but we know that we still are far from realizing this goal in all respects. We argue that no one should be forced to leave school because of economic considerations, but we know that many students still do. We would like all of our States and communities to have equal—and this means equally good—public schools, but we know that the quality of our schools varies from State to State, from county to county, and even within the same community.

The quality of education in our best schools and colleges is high by any standard. Our outstanding graduate schools are probably the world's best. Moreover, we can afford to be proud of the accomplishments of our educational system in its quantitative aspects. Educational opportunities are available to all of our young people through at least the high school level. These days more than three-fourths of our boys and girls 14 through 17 years of age are in school. The millions of students we have provided for at the college level represents an increasingly important extension of the American goal of providing maximum educational opportunity for all.

All things considered, therefore, we as Americans can justifiably be proud of our educational ideals and our accomplishments to date. But we should and do realize the degree to which these accomplishments still fall short of our aspirations. We could not afford to be arrogant on this score—even if the American temperament permitted such an attitude. Neither should we be masochistic, however, in our analysis of what is wrong with our educational effort. As we contemplate the awesome mass of human knowledge, the problems that face us in attempting to find better ways of passing on to later generations this accumulated knowledge should make us both humble and determined.

The gaps that separate our goals and our accomplishments in education are several. I have mentioned our large college enrollments, and the numbers are impressive. But we know that many students of high ability never get to college—and this represents both a major national loss and an unfortunate deprivation for the individuals involved. New ways of coping with this problem have been found recently and others are under study; I am confident that this problem will become less acute if we persist in our efforts to assure equal opportunity for all.

Shifting patterns in our population constantly dictate changes in our educational activities. For example, the total number of young people 14 through 17 years old dropped more than a million in the decade from 1940 to 1950, but is now at an alltime high. In the period from 1940 to 1952 the number of 18-year-olds in our country fell from 2.5 to 2.1 million. For the past 10 years, the number reaching 18 each year has risen sharply—and 3.8 million young people will reach college-going age in 1965; by 1975 we will have 4.2 million in this age group—almost exactly twice as many young people of age 18 as we had in 1952.

The implications of these numbers are important in considering the quality of education. We can be sure that our high school enrollments will continue to rise. An increasing fraction of each age group will probably enter college. We will therefore have no difficulty finding students to teach. The problem, rather, will be one of maintaining and improving the quality of their education. To find sufficient funds to expand our school facilities to provide room for these larger numbers will be an enormous task in itself. But we must simultaneously and with equal emphasis seek the resources which will assure qualitative as well as quantitative growth in the Nation's educational enterprise.

There are so many reasons why we should improve the quality of education in the United States that it perhaps seems pointless to comment on this matter. I do want to underscore one such reason, nonetheless. At the same time that we see unprecedented numbers of youngsters moving toward our schools and colleges, we find that all the evidence points to two characteristics of American life with which we have not had to cope in past decades. Automation in commerce, industry, and Government will bring with it requirements for workers who have had more education, while at the same time unskilled labor will become less and less necessary. More education—of higher quality—will be essential under these new circumstances. An ancillary development which we frequently overlook is the likelihood that these new circumstances will lead to a shorter workweek for millions of Americans. The creation, in effect, of a large-scale "leisure class"—individuals who spend no more than one-quarter of their waking hours at work—will place new strains on our culture if we do not provide these individuals a kind of education which will enable them to utilize their leisure time more meaningfully.

This is not a matter we can postpone, because many of the students in our elementary and high schools today will, long before their working years are over, face this issue of finding significant ways of using their leisure time. I am convinced that our soundest way of approaching this difficult matter is to assure all our students a basic grounding in the humanistic studies. Those who have come to enjoy literary and artistic masterpieces will have no difficulty in finding ways of employing all the leisure they may have—and at the same time will find their lives more rewarding and significant.

It is difficult to define the word "quality" in any context. Its use almost always involves value judgments which are by no means uniformly accepted. In the educational domain, where almost everyone considers himself to be an expert, it is particularly difficult to find words which satisfactorily describe education of high quality. I have neither the wisdom to do so nor the temerity to try. What I propose to do, instead, is to give some points of view that I believe are related to the problem of improving the quality of American education, explicitly at the elementary and secondary school levels.

American schools have been expected to provide a wide variety of educational services. It is pointless to speculate on whether our secondary schools could do a better job if they were to be transformed into single-purpose institutions, focusing exclusively, let us say, on the task of preparing students for college. Our high schools will without doubt continue to accept these broad responsibilities, and it is my conviction that they should.

In their striving to achieve higher quality, therefore, our schools will need to assess and reassess at all times the relative emphasis they give to the various components of their multiple task. Too much emphasis on any one component can lead to weakening others. So long as resources are limited (a situation I fear we will continue to face indefinitely), it will be necessary to consider with care whether available funds are to be spent, for example, in improving the equipment for teaching home economics or the equipment for teaching physics. In planning a new school building, one should give due attention to providing adequate library space as contrasted, say, with providing a larger gymnasium. Such decisions as these frequently involve considerations of a complex nature, and community pressures sometimes push in the direction of choices which are not compatible with a balanced educational effort. If we are to achieve higher quality in our education, however, school leadership at all levels must plan wisely and then must find ways of convincing others that the plans thus developed are the ones which will enhance most fully the school's effectiveness.

The most important element in any school is the quality of the teaching. It is axiomatic that the salary and the status of teachers are factors that are intimately related to the level of teaching competence in a given school or school system. Efforts are being made to provide adequate salaries for teachers, and these efforts are slowly having some effect. Much remains to be done on this score, however, and particular attention should be given the problem of reducing the unreasonably large geographical differentials in teachers' salaries.

Many of our school buildings have long since outlived their usefulness. By any modern standard they are obsolete and need to be replaced with more adequate facilities. Even so, we have too few schoolrooms. So long as these conditions persist, the quality of our education will remain lower than it should. On this point, particular attention must be given to the situation which exists in our great cities. The rapidity of growth of our urban centers of population has led to enrollment increases which in many cases have exceeded the rate at which the cities could provide adequate school facilities. As a result, thousands of children are being educationally shortchanged in that they are being provided only a half day of schooling, or are being taught in antiquated buildings—or both.

The fact that we have in our schools many thousands of dedicated, well-prepared teachers is well known to all of you. At the same time, however, I am sure you would agree that there are many conscientious and hard-working teachers at all grade levels who desperately need and want better training in the subjects they are teaching. Some of these are teachers whose initial preparation was reasonably good, but who now need to be given the opportunity of "catching up" with progress in scholarship in their various fields. Others badly need basic training to deepen their understanding of the fields they teach. Those of us who are particularly interested in science like to point out that the rapid rate at which progress is being made in our area of concern makes refresher training especially important for teachers of science. However, as scholarship in other fields broadens these areas of knowledge—or improves the techniques of imparting knowledge—it is also important for teachers of these subjects to keep abreast of such changes.

Interest in this problem of revitalizing inservice training has led to the development of a variety of programs specifically designed to improve the subject-matter competence of teachers. The National Science Foundation's teacher-training programs are well known. Comparable programs for teachers of modern foreign languages and for school personnel concerned with guidance and counseling are being carried forward by the Office of Education. Although more needs to be done in these fields where activities are already proving highly significant, it is equally urgent that we find ways of broadening these efforts so that teachers in other fields can be provided similar opportunities for self-improvement.

Even in those cases where buildings are reasonably adequate and where the teachers have been carefully selected, however, there are still many problems which need to be solved. One of the most important of these arises from the need for updating courses and curriculums and utilizing in fuller measure the aids to instruction which now exist or can be produced.

In the early days of this century, the tools available in almost any blacksmith's shop would suffice to repair the latest model horseless carriage. Today, the tools required to service a modern automobile are highly specialized and technologically sophisticated. Of necessity, the mechanic's tools have kept pace with the increased engineering complexity of the products of Detroit.

Unfortunately, the rate of growth of research and development in education has not kept pace with similar activities in other areas of importance to the Nation's progress. Educational research has received far too little attention, and the funds available to support significant research in this domain have been trivial in comparison with the magnitude of the problems we should be attempting to solve. Those who have specialized in educational research have made significant contributions under difficult circumstances, and we all owe them a special debt because of our failure to realize the importance of their efforts.

Research designed to lead to a further understanding of how children learn has unfortunately not been pushed as hard as it might and should have been. This is an area which should be developed much more fully, and as rapidly as well-qualified investigators can be persuaded to undertake such research. Our present knowledge of the ways in which children learn is much too limited to provide adequate guidance in the development of new teaching materials and new techniques of instruction.

It will require years of further study to develop our understanding of the learning process to the point where the results will lead us directly and with assurance to better ways of ordering and presenting subject matter in the classroom. In the meantime, we can improve the quality of education through carefully designed empirical experiments. The importance of such efforts has already been demonstrated in modern foreign languages, in mathematics, and in science. In each of these areas, highly competent scholars—working intimately with teachers—have developed new instructional materials which have already been shown to be far superior to the materials they are beginning to replace. Project English—an effort designed to produce improved instructional materials for the teaching of our own language—has just been launched by the Office of Education. Thus far, however, we have only made a start toward the goal of placing in the hands of our teachers—in all fields—the kinds of instructional tools they need to raise the quality of education to the level that can be achieved.

Recently I had the privilege of attending the final sessions of a 2-week working conference at which a group of teachers and scholars from a wide range of disciplines considered in depth the possibility of devising new instructional materials of various kinds for the humanities and the social studies. The outcome of this group's work cannot be summarized in a few words, but it is fair to say that they emerged from their extended discussions with the conviction that much needs doing and that much can be done to improve the quality of preuniversity instruction in these areas, through the production of new materials for classroom use. Many of the university representatives indicated not only a willingness but also a desire to help in the development of such materials.

Similar conferences have been held elsewhere and will occur with increasing frequency as those who have participated in some of the earlier discussions succeed in infecting their colleagues with the idea that cooperative efforts in these directions can have a major impact on the quality of American education. I am confident that such discussions will lead to productive effort, and that these efforts—extending across all fields of study and touching all grade levels—will introduce a new spirit of constructive ferment into our schools.

You have heard a great deal about the work that has been or is being done to improve the materials available for the teaching of science. The National Science Foundation is vitally interested in these efforts, and hopes that it will be possible to continue providing support for such activities. I am sure that you join with us in hoping that parallel efforts in the other fields of study can be rapidly expanded.

I have said very little about the importance of science and mathematics in assuring educational quality. It would be presumptuous of me to assume that I could provide any new insights on this matter. I do want to say, however, that science is a particularly good example of the point I made earlier concerning the importance of stressing quality of instruction as contrasted with the problem of securing more students. In the latest year for which I have statistics, the school year 1958–59, 4.67 million of our high school students studied science. Perhaps a good many of the students of that year who were not studying any science (some 40 percent of the total) should have been counseled or required to do so. But the fact is that close to 5 million students were enrolled in science courses—courses which in many cases were taught by conscientious but ill-trained teachers, using poor facilities and materials which were far from adequate to convey fully and clearly an understanding of the subjects being taught. The number of students in our high school science courses continues to grow, and we must therefore continue our efforts—already moderately successful—to improve the subject matter competence of our teachers and to provide instructional materials of high quality.

Educational quality cannot be increased overnight. Efforts along many lines are required. The problems are complex and interlocking. These problems are not insuperable, however. Some of them can be solved with relative ease, if sufficient funds can be devoted to their solution. The obvious example here is the problem of school buildings. Others cannot be solved with money alone, because they require contributions of time and effort by teams of outstanding scholars and teachers. Course and curriculum revision projects fall in this category.

All elements of our organized society can and should contribute to the massive task we face in trying to reach the American goal of equal and full educational opportunity for all. Private citizens and professional societies, school boards and industrial groups, chambers of commerce and labor unions—all can and must contribute in various ways to the discussions and the efforts that are needed.

I have no doubt that local control of education is firmly and permanently embedded in our American tradition. One result is, however, diversity of quality. We have in recent years recognized the fact that the problem of improving the quality of education throughout the United States is one which deserves national attention and appropriate kinds of Federal support.

Federal funds are already helping to improve the quality of education. But Federal support for educational improvement will not and should not be viewed as *the answer* to our problems. Increased efforts on the part of local and State governments are and will continue to be essential.

"Quality of education" is a phrase we might well use with increasing frequency, as a way of reminding ourselves both of the great strengths of American education and of the faults and weaknesses we see in it because of our passion for progress and improvement. I predict that our children—and indeed our great-great-grandchildren—will in their adult years find themselves unsatisfied with their schools, and will continue to search for ways of improving their quality. If our efforts to make our schools better are continued, and if my prediction concerning our descendants is in fact fulfilled, education in America will become and remain the world's standard of quality.

Science and Education Today

M. H. Trytten

Director, Office of Scientific Personnel, National Academy of Sciences-National Research Council

WE LIVE in a highly permissive society. Each person may choose his interests, his vocation, and his preparation via a choice of curriculums. We have more or less tacitly assumed that, when all these choices have been made, the sum total will be optimum for the needs of society and the Nation. We may have to inquire whether in fact this can be true, and, if not, what can be done about it. And indeed, we are doing so, as the National Defense Education Act and other programs attest.

One thing we can do is to strengthen science education to meet at least our pressing need. We are facing in our country great responsibilities in science education, not only to meet the demands of new programs to which the Federal Government is committed but also to meet other demands which appear to be growing apace, as well as to develop meaningful science education for the citizens of our country who will be living in an environment more and more affected by technology and more closely related to it. This challenge will be felt increasingly as time goes on all the way from graduate school, at one end of the scale, down through the colleges and the secondary schools and the elementary schools.

Perhaps it might be worthwhile to recapitulate a few facts about the development of science as an integral part of our culture, with special reference to more recent developments, as a background for some of the things I should like to dwell upon.

Development of Science

First, let me state that I find it convenient to think of the development of science and technology in four eras. The first of these may be thought of as the "era of sporadic discovery." This would cover the time up to the 17th century and the advent of the Enlightenment. In this era while notable advances were made at a number of times and places, they were in a sense disjointed and led to no systematic growth of what might be called a scientific structure.

The second era is signalized by the enormous accomplishments of such persons as Bacon, Newton, Leibnitz, and Galileo. As a result of their work, for the first time a structure of science began to develop. It was the work of the next two centuries to add to this structure, to fill it out as a result of both theoretical and experimental work, and thus to lay the groundwork and create a discipline of science. To a large extent, especially toward the end of this era, science had become a function of the universities. Its motivating drive, however, was primarily intellectual, as an outgrowth of curiosity and a desire to understand the workings of nature.

This third era begins with the application of science to practical affairs. In some respects it may be thought of as an older movement, since practical uses of technology occur even in antiquity, but as a significant affair its momentum began to be appreciable in the middle of the 19th century with the beginnings of technological industry such as transportation, communications, power industry, and the chemical industry. A later and highly important phenomenon in the technological industry was the establishment of the industrial research laboratory.

The importance of this development in the last six or eight decades is probably underemphasized in the context of the development of science and technology. It was with the establishment of the industrial laboratory that deliberate and organized efforts to add to our scientific knowledge, to seek out in a systematic way the applications of science to the practical uses of man, and to create a methodology for the purposes were made. Science moved out of the universities into the realm of commerce and industry as a sole locus of scientific development. The resulting acceleration of scientific development added to rather than subtracted from the role and effectiveness of the universities. The universities were under more pressure to train scientists, and the flow of scientific knowledge and instrumentation from the industrial laboratories aided science in the universities.

It is to be noted here that to the intellectual drive was added the profit motive, such that two forces led to the accelerated exploration of science and the exploitation of its findings. The profit motive, besides being the additional drive, was also the limiting factor, in that technological development was limited by the possibility of profitable practical application.

The fourth era is, by and large, dated from World War II. It was at this time that the interest of the Federal Government was added as an almost dominant factor in the acceleration of science. Because of the mutual interest involved, Federal expenditures for scientific research and development increased enormously. They have since continued to increase as every new area of national interest began to develop in which research and development promised results significant to the challenges facing the Federal Government. Consequently, we have had enormous increases over the last decade and a half in the budgets of the Armed Forces, the Atomic Energy Commission, the National Institutes of Health, the National Aeronautics and Space Administration, and the National Science Foundation.

A recent release of the National Science Foundation shows that research and development expenditures have increased in the United States just in the last 8 years from about $5 billion a year to over $14 billion a year. This may be compared to the period immediately preceding the war when expenditures were measured in the tens of millions of dollars. It is to be noted here that the limiting conditions as distinct from the other eras are only decisions on the part of Federal agencies and the Congress as to what is in the national interest.

A third force has been added beyond that of intellectual curiosity and the profit motive—that of the national interest.

Scientific and Engineering Manpower

Much effort has been given over the past few years in attempting to reduce to some quantitative basis the supply-demand equation related to scientific and engineering manpower. None of these efforts has been wholly satisfactory. Our society is one of high permissiveness and loose organization, characterized by a free economy and an aversion to controls. Consequently, practices differ over the many units in our society. There are differences in nomenclature, organization, function, and standards which almost seem to defy analysis and the synthesis into a meaningful matrix of all the factors and considerations needed for a reliable measure of either supply or demand. Nevertheless over the years some progress has been made. One such comprehensive study has been made by the Bureau of Labor Statistics for the National Science Foundation. (NSF publication No. 61-65, *Long-Range Demand for Scientific and Technical Personnel.*) It is useful as one step forward in visualizing trends over the next decade.

The findings indicate an increase of scientific and engineering employment averaging over an 11-year period about 85,000 per year. To this must be added about 21,000 per year for replacements due to death and retirement. The losses caused by migration into other lines of work, into management, into entrepreneurial functions, and into public and other services are certain to occur but are more difficult to measure or estimate.

In the field of engineering alone, needs for new personnel are indicated at a level of about 81,000 per year. In the sciences the needs for new personnel are estimated in this report at about 25,000 per year.

On the supply side in engineering, the report notes that something less than one-fourth of the engineers in our economy do not have college degrees but enter the profession from other fields, from less than college degree training experiences or from other sources, leaving some 62,000 per year to be procured from the engineering colleges. It should also be noted that about one out of seven engineers does not even enter the profession. Thus the Bureau of Labor Statistics report indicates a need of something like 70,000 engineers per year from the engineering colleges. About 45,000 have now been graduated, including those with master's and doctor's degrees.

In the sciences the balance between supply and demand seems closer. However, the report is less satisfactory, since it was not possible at the time it was in preparation to reflect the substantial new demands that the future promises in view of the activities of the space exploration programs, the health programs of the National Institutes of Health, the possible demands for the export of talent abroad, and other accelerating programs in which the national interest is involved. These demands are now looming greatly on the horizon. As one example, there is the case of the preview of the programs of the NIH, as stated in hearings before the Subcommittee on Appropriations of the House of Representatives. The report of these hearings indicates that a probable budget of the NIH over the next 8 years will rise to approximately $3 billion per year in 1970. It is estimated that such programs will require new personnel and personnel to replace those moving out due to death and retirement, or a total of about 45,000 additional persons in the next 8 years. At the doctoral level alone, this will mean new personnel at an average rate of about 2,800 per year. Since the personnel needed will be predominantly in the biological and basic medical sciences, it may be noted that in 1960 American universities graduated fewer than 1,800 yearly at the doctoral level.

Estimates can similarly be made of the personnel needs resulting from increased activities of the National Aeronautics and Space Administration. While the probable budget figures for the NASA may move to the level of $5 billion per year in the next 3 or 4 years, the estimate of what this will entail with respect to the need for additional personnel trained to the doctorate level is less easily understood. However, conservative estimates would seem to indicate the need for at least 1,000 additional persons at the doctoral level in the relevant sciences. There are, however, other areas in which the need for personnel also seems to be definitely on the upgrade, although the numbers will not be as large. Much may be made, for example, of the field of oceanography, which has now been recognized as an area in which the Federal Government has a substantial interest. It is quite likely that Federal subvention in this area will increase rapidly over the next few years as the United States becomes more and more dependent on the oceans for defense and as an ultimate source of raw materials.

Recently there has been a recognition of the fact that problems of environmental health due to the rapid growth of technology are becoming of considerable concern to the Nation as a whole, and specifically to the National Institutes of Health. Serious study has been given to this over the last few months, and it seems likely that rapidly stepped up Federal activity will be called for with the establishment of a possible national institute of environmental health and that a substantial increase in numbers of people trained in this area will be required.

Another area related to technology probably should be mentioned. It has become apparent lately that the growth of the power of technology has now come to the point where substantial social and economic problems are being created by technological developments. For the solution of these problems people will be required who, on the one hand, have an understanding of the technology involved, the technology of quantitative research and research design, but who also have a sufficient background in the behavioral sciences involved.

Finally, much should be made of the fact that in the future the role of the Government in foreign assistance, including education, especially in the scientific and technical areas and in the development of science and technology itself, will undoubtedly increase and probably increase rapidly. Consequently, the export of talent may be expected to be a factor to be reckoned with in the future.

Rate of Training for Science

What then of our rate of training? You are probably all aware of the fact that so far from being an increase, there is an apparent decline in engineering enrollment. The enrollment percentages in engineering at the freshman level have declined from the historic level of approximately 9 percent of entering freshmen to something now more closely approximating 6 percent. In actual numbers the decline has been moderate, but nevertheless a definite decline.

At the level of the doctorate in sciences and engineering, historically in our country there has been over a number of decades a steady increase in training to the doctorate, approximately a 7-percent increase per year. However, during a part of the decade of the 1950's, in some fields the rate of increase was less than this amount and is only recently beginning to show more rapid rise and an approach to the historic rate of increase of 7 percent per year. The important point, however, is that this is to be compared with an increase in annual expenditures for research and development of from 30 to 40 percent per year.

In partial alleviation of this apparent imbalance between the rate of training and the rate of growth of science and technology, it might be noted that there are in the United States today a substantial number of foreign scientists who are guests of our universities and who participate in programs, especially of basic research. This phenomenon has apparently been on the increase. It is not enough to make up the difference, but it does add an interesting factor to the situation.

Emerging Goals in Science Education

Such studies and surveys as those of the Bureau of Labor Statistics are helpful in illuminating and making concrete the immediate situation and the challenge facing our educational system in supplying the manpower for science and technology in the coming years. They have, however, their limitations as we consider emerging goals in science education. They must deal with tangibles. They must deal with employment opportunities, with money appropriations, with trends which have been established over a sufficient length of time to have plausible continuity.

It is in the very nature of science, however, that its growth points are unpredictable. There has been no time in the past when one might have foreseen the key developments which have had such enormous effect on the direction, magnitude, and influences of resulting developments. No one expected Faraday's discoveries to result in the power industry. The three-electrode vacuum tube was a plaything; it was hardly conceivable that it would lead to such enormous consequences for communications and for research. The splitting of the nucleus could hardly have been expected to have the manifold profound results it has had in generating a whole new scientific and industrial realm.

The goals for science in the future are, therefore, of necessity obscure. If anything may be thought to be fairly certain, it is that new and equally important developments are latent and implicit in the further developments of science. It is unthinkable that this phenomenon of science has run its course. Indeed, the level of expenditure for research and development in our day, when research and development is one of the largest industries of our time, almost certainly promises accelerated emergence of key concepts, ideas, and discoveries. They will emerge to find their places in the world of science and technology and to generate new directions of research and of applications.

Besides these trends inherent in the very nature of science and discovery, there are at least two other factors which will of necessity affect the goals of science in the future. One of these grows out of the increasing stresses produced by the accelerating growth of technology itself added to the growth of populations throughout the world.

The rate of consumption of natural resources, both renewable and nonrenewable in our country and around the world, has increased geometrically with time. Projections have been made by various authors and specialists as to the length of time that will ensue before these resources will be in short supply. There is no need here to quote these statistics. The picture is perfectly clear that in the not too distant future the curves of rising demand and dwindling supply will meet. Whether this occurs in 1970 or 1980 or in the year 2000 will depend on the particular commodity concerned and on the trends in technological developments. It will depend also for any one country on its access to world resources as well as its own. In any event, however, this matter will become increasingly a challenge. There is no doubt at all that this problem will provide one of the preoccupations of science and technology for the future. Involved will be the beneficiation of ores, the technology of miniaturization, the improvement of alloys and substitute materials, and all the possibilities of better utilization of existing resources.

Another facet of the manpower problems of the future is the growing interrelationship between science and technology and the environment, whether human or physical. The growing complexity of instrumentation is one example, since this involves in design in an even more intimate way the man and the machine. This field of human engineering is of growing significance, requiring more intimate knowledge of technology by the social scientists concerned, as well as more understanding of human requirements and limitations on the part of the scientist or engineer designing the instrument.

This is only one of the many situations in which science and technology must interrelate with the behavioral sciences. The design of highways now is increasingly a matter involving questions of land use, of urbanization, of themes of traffic flow, of social welfare, and of group psychology.

The important fact is that the interplay of complex systems, both scientific and technological, as well as behavioral, presents complexities which call for sophisticated research design, quantitative method and adaptation of research to many and variable problems which will swell the demand in the future for a new and different type of research personnel.

Warren Weaver, past president of the American Association for the Advancement of Science, expressed it this way in a letter to Robert Morison and quoted by him in the fall 1961 issue of *Daedalus:*

> I have a very strong conviction that the "new form of excellence" required by science over the next half-century will in considerable part consist of techniques for dealing with broader problems, larger problems, problems which arise when a moderate number (three to one hundred, just as a shot) of small problems are organically interrelated.
>
> One can start with very obvious and oversimplified examples. The day is past, I would claim, when science can properly treat food supply as an isolated problem, birth rates as another, public health as another. The whole body of servomechanism and feedback theory; many of the techniques of operations research; the emerging kowledge concerning information and communication theory—these are all groping toward the capacity to deal with problems of organized complexity.
>
> We have been great at producing bits of information, fragments of knowledge. We now need to devote more attention to the fitting together of these bits, to the broader interrelation, and hence to broader utilization. . . .
>
> We have to humanize science and give more general meaning and structure—and even value—to it.

Probably first among all the goals for science teaching which now seem increasingly important and which lack proper conceptualization is that of science for the citizen. The matter can be looked at from many points of view. On the one hand, there is the extraordinary importance of science in public and national affairs. In a democracy in which the citizen is the ultimate determinant of action through his ballot, there is a dangerous hiatus developing between some of the most important affairs of state and the understanding of them by the citizen. In the March 5, 1960, issue of the New Yorker, there occurs this paragraph as quoted by Weaver:

> These are hard times for the layman. He is thought no longer competent to work out his own opinions on many matters—even many that touch him intimately. His very survival has become the property of committees and the subject of learned arguments among specialists. He has little to say, poor fish, being largely ignorant of the information upon which plans for him are based.

Obviously this can be applied to science—to fluoridation of water; to fallout; to the role of chemical and biological agents in agriculture and in conservation; and to the control of food, drugs, and occupational and environmental hazards.

But the matter goes beyond this practical point. It is also a question of the spirit and character of our age. This is an age of science. Education is supposed, among other things and perhaps most importantly, to orient the individual to the environment in which he must live and work and find his enjoyments and satisfactions. Science and technology are today the main components of that environment, whether one speaks of the physical environment or the intellectual environment. The average citizen today cannot be at home in that environment if he does not achieve some degree of rapport with it.

It is not necessary that he be a physicist, a chemist, or an electronics expert. But he should know the nature of science and something of how it works, have some feel for and understanding of how a scientist works and thinks, and eventually develop a decent respect for what science can do and what it cannot do.

He need not know how to assess the exact reliability of a given scientific study of the dangers of fluoridation of water, or of its lack of danger. He should know that science can estimate them, however, and that the result can give practical guidelines for practice. He need not know how to examine the age of a fossil, but he should know that reliable scientists do know how and can be trusted. He should in addition have some insight into the relevant methodology.

What has been said here and other such considerations have convinced many persons of the increasing importance of the secondary schools as a factor in the production of personnel in the scientific and engineering disciplines.

Unused Potentials

In the Office of Scientific Personnel there is maintained a roster of persons who have attained the doctorate degree from American graduate schools over the past several decades. More recently it has been possible systematically to obtain information on the geographical and high school origins, as well as the undergraduate origin of these people who have attained the doctorate degree. In plotting these results, interesting information has become available on the pattern of our educational system as it relates to personnel with advanced training. If one plots the percentage of high school graduates who have attained the doctorate degree in terms of the size of the high school as measured by the number of graduates per year, it becomes apparent that the size of the high school is an extremely important factor. A curve results which starts almost at zero for high schools graduating from zero to 25 per year, rises very slowly for high schools graduating 25 to 50 per year up to high schools graduating about 400 per year. Thereafter the curve stays approximately constant up to a size high school graduating about 1,000 per year. Beyond that point the curve rises more sharply, since among this category are some of the large selective and specialized high schools.

It seems quite clear, therefore, that the small high school graduating fewer than 400 per year finds it difficult to provide the environment which can properly equip a student to enter college and proceed satisfactorily in college and then enter the graduate school for successful work. The smaller the high school, obviously, the less the student seems to be conditioned to go on to successful work in specialized science and engineering. It may be that in educationally underprivileged high school students may be found one of our greatest unused potentials.

Obviously, the greatest unused potential in the United States is that of women. This phenomenon is, of course, well known. Nevertheless, as one looks at the relative figures indicating the percentage of women in the scientific and engineering areas in colleges and the graduate schools, the disparity seems to be more than significant. It would appear that in this area of the use of women, the greatest progress should be potentially possible. Those of us who have been in teaching at the secondary and college levels would, I am sure, agree that there is no fundamental reason why women cannot accomplish as much in these areas as can be done by men. It would also seem possible that special efforts to interest women students can be enormously successful and significant in the total picture of manpower resources of the Nation.

Another serious problem that, in my estimation, needs emphasis is the tendency in our country to assume that training in high school and in college in the field of science and mathematics is primarily for those who intend to make a life career in these fields. There seems to be a tacit assumption that other students need no courses in these fields or at best only watered down or descriptive courses.

In the first place, there are few people today who will not in one way or another either be affected in their work by technology and should therefore understand it or will have to make decisions in which it is a factor. Even our functioning as citizens in great national issues of a political nature more and more has some content of technology involved. Indeed, if education is the process by which an individual becomes sympathetically aware of and develops an understanding of his environment, then the educated individual must realize that a larger and larger part of his environment is technological in nature.

Secondly, a thorough grounding in the basic sciences may provide the opportunity for the individual at any time to change his career and professional goals if he so desires. Failure to include enough science and mathematics in his curriculum will most likely forever preclude him from turning in that direction later on.

And in the third place, as was indicated earlier, many fields such as those of the behavioral sciences in the future will of necessity become more involved, and sometimes quite intimately, with some phases of science and technology. Even to have the opportunity to grow in some of these fields will depend on the degree to which the individual has mastered science and mathematics.

This leads directly to the last point I wish to make which has to do with the guidance and counseling movement today. The importance of guidance and counseling is being recognized at the national level more and more clearly by educators and, indeed, by political leaders and many others who have perception of the problems of education and interest in it. I would hope that at the State level the persons responsible for guidance and counseling activities would work very closely in the use of the guidance and counseling movement for strengthening training in mathematics and the sciences in the elementary and secondary schools. It is my impression that in many schools there is a tendency to delay decision as to the ultimate career intentions of the individuals until such time as they have "had the opportunity to see" available possibilities and to make appropriate career decisions. In general this has a certain amount of appeal. However, if it means that in the meantime the individual neglects relevant prerequisites, he may find that when he comes to the most important decision he has precluded many possibilities. It would also seem to me highly important that those involved in the guidance and counseling movement understand the significance of science as an element in a broad liberal education appropriate for life in the modern age.

Implications for Science Education

J. Darrell Barnard

Chairman, Department of Science and Mathematics Education
New York University

DURING THE PAST 10 years more man-hours have gone into projects having to do with the improvement of science education in the schools of America than during any previous 50-year period in the history of education in this country. The primary motivation for such a phenomenal effort has been to increase both the quantity and quality of our scientific manpower resources. Although there is substantial evidence that the effort is beginning to pay off, the task is far from being completed—if, in fact, it will ever be completed.

The problem of improving educational practice is a persistent one. Because of the multiple variables involved in the educational process, the problem will never be completely solved. To complicate the problem further, these variables interact between two dynamic enterprises, science and a free society.

We must not make the complacent assumption that the new science courses and the intensive effort that has been made to upgrade the backgrounds of science teachers has or will ultimately raise the level of science teaching to where we, and those who follow us, will hopefully expect it to be some day. As happens in scientific advancement, each step forward in our understanding of the educational process opens up new problems. Each new problem must be dealt with in our efforts to improve the efficiency of educational practice. The point I am trying to make is simply this: science teaching will be improved only as long as we persistently work at it. There will never come a time when we can sit back and say, "The job is done".

Whereas the primary goal of our recent all-out effort to improve science education has been focused upon the education of the future scientist, we should not become so prepossessed with this extremely worthy goal that we lose sight of the masses who must also be educated in science. These are the folk who will never become scientists. They will become the lawyers, the schoolteachers, the school administrators, the clergymen, the businessmen, the housewives, the farmers, the cattlemen, the watermen, the truckdrivers, and the merchants. Although they will not contribute directly to scientific progress, many of them will be making decisions which indirectly affect science and the ways in which its discoveries are applied to human welfare. Each of them will seek to live a reasonably orderly and satisfying life in a society that is being increasingly influenced by science. All will be called upon to modify onetime respectable concepts which advancements in science will inevitably render untenable. It is clear that science must become an integral part of the education of all from the elementary school through college.

Science in the Curriculum

I am certain that the science curriculum builders in every State have assumed that it is their responsibility to build for all students science curriculums that are sequential and developmental from the elementary school through the secondary school. But before anything of real significance will result from this commitment, we will need to take a hard look at our points of view regarding objectives, the learning process, and evaluation in science teaching.

As educational leaders we have developed a laissez faire attitude toward certain practices which should be vigorously challenged. The most critical of these is the manner in which curriculum workers, course-of-study makers, and teachers have dealt with objectives of science teaching. I have yet to see a curriculum or a course of study developed by educators that did not have in its preamble a well-formulated list of objectives. This is as common as the American flag in every school. In fact, the statements of objectives are frequently as similar as American flags, and, like flags, they come in different sizes. There are long lists, medium-sized lists, and short lists—but all reflect the same basic statements of objectives that have been in the professional literature for the past 30 years. I have no quarrel with this practice as far as it goes—in fact, I am disturbed by those who develop science courses without stating clearly the objectives which the courses are to achieve. But when I reflect upon my disturbance about such malpractice, I am impressed by the possibility that those who develop their courses without first paying allegiance to the sacred objectives are intellectually more honest than those who go through the formality with little or no intention of letting the objectives get in the way of their developing a course or curriculum in keeping with the conventional patterns. Nor does there seem to be any predisposition to follow through with teachers to make certain that they understand the objectives and reflect them in their teaching.

Let me give you an example of what I mean. The "critical thinking" objective and the "understanding of basic concepts" objectives are two common denominators in practically every list that I have seen. They may be stated in different ways but you'll find them there. When you examine some courses of study you find that the range of their content is of such an order that to cover it in ways that will develop understanding to any reasonable depth is impossible. When you examine the suggested learning activities it is difficult to identify clearly "critical thinking" as one of the outcomes.

How are these objectives reflected in classroom practice? Investigators [1] have found that teachers either do not accept these objectives or they do not comprehend them and, consequently, do not provide for them in their teaching.

Closely allied to the laissez faire point of view about objectives is an all-too-common point of view about learners and the learning process. Not long ago I took part in a discussion of what to do with the slow learner or the nonlearner in science classes. One member of the group commented that in his school they did the only thing that could be done with slow learners. They sifted from the standard biology course a few simple facts that were pertinent to the well-being of the students (such as the number of times the normal heart beats per minute) and drilled the slow learners with these facts. In this way he felt that science teachers were meeting their obligation to do something for the slow learner. This incident illustrates an all-too-common attitude about learners and the learning process in science, that of filling the mind with facts. In turn, this all-too-common practice reflects a concept of mind that is no longer tenable.

Directly related to their points of view with regard to objectives and learning is the attitude which practitioners take toward evaluation. As long as achievement in science is judged primarily in terms of verbalization of definitions and factual material, any discussion of or planning for the accomplishment of the more significant objectives of science teaching will be largely a waste of time and effort.

To elaborate further about the importance of curriculum builders', supervisors', and teachers' giving more serious consideration to objectives, learning, and evaluation, I would like to extend discussion of the two objectives of science teaching referred to earlier.

Concepts and Processes

It would seem there is still general agreement that a good science program should result in an understanding of certain basic concepts of science, on the one hand, and the processes of science or methods of critical thinking, on the other, and, furthermore, that concept and process are inextricably related in the scientific enterprise. This means that scientific conceptions have not been made known to man on tablets by some supernatural, universal authority, but rather have been wrested from nature by man through the persistent application of the intelligence with which he has been endowed. By this laborious process man has come to his present understanding of the world of nature.

---

[1] Wilbur L. Beauchamp. *Instruction in Science* (No. 17, Monograph No. 22). U.S. Office of Education. Washington: U.S. Government Printing Office, 1932.

Ellsworth S. Obourn. "Assumptions in Ninth-Grade General Science." (Doctoral dissertation, New York University, 1950.)

Insofar as the concept-process purposes relate to teaching and learning science, correspondence with the scientific enterprise is striking. The research on learning has shown quite clearly that no one, not even a science teacher, can give another person an idea—a concept. He must think his way to the idea if it is going to become his concept. When I say "his concept" I mean just that. It becomes his personal possession only when it becomes amalgamated within conceptual schemes and patterns which are ever emerging in the unique thought contexts of the individual. This amalgamation occurs through a critical thinking process whereby the individual actively applies the intellect with which he is endowed. This is another way of saying that the learner must get meaning out of that which he is taught if it is to be learned, that meaning develops from experiences that get the learner involved in critical thinking. The old cliche, "We learn by doing," should be revised to read, "We learn by doing when we are thinking critically about what we are doing." A common reaction to this point of view is that we don't have time for the learner to discover everything on his own. My belief is that he'll never learn it in any other way.

Recall the research of Powers[2] in which he found that merely because students can verbalize concepts in chemistry, we cannot assume they understand these concepts. In fact, he found that a relatively small proportion of the good verbalizers of chemistry possessed an understanding of chemistry as it was conventionally taught.

This research, coupled with that of Tyler[3] and Downing,[4] would seem to indicate that much of what has gone on in science classes was a tragic waste of time and effort. Tyler found when science students were taught with emphasis upon verbalism (learning definitions and specific facts for recall) that one year after the science course they had forgotten about 80 percent of what they knew at the time the course was completed. On the other hand, when students were taught to think their way to an understanding of selected principles of science, their retention curve did not drop off but went up during the year following completion of the course. In several studies conducted under Downing's direction, it was found that not more than about eight principles of biology could be learned with understanding by high school students in 1 year.

---

[2] S. R. Powers. "The Correlation Between Measures of Mental Ability and Measures of Achievement in Chemistry. *School Science and Mathematics*, 28:981–986, December 1928.

[3] Ralph W. Tyler. "What High School Pupils Forget." *Educational Research Bulletin*, Ohio State University, 9:490–492, Nov. 19, 1930.

——. "Permanence of Learning. *Journal of Higher Education*, 4:203–204, April 1933.

[4] Elliot R. Downing. "Teaching Units in Biology—An Investigation." *North Central Association Quarterly*, 5:453–457, March 1931.

As far as I know, the findings from these studies have not been refuted by subsequent studies in science teaching. Therefore, if we as specialists in science teaching believe that decisions about what to teach in science and how to teach it should be based upon experimental evidence, we are morally and ethically committed to work for a major reconstruction of science curriculums and a drastic reorientation of classroom practices. In fact, if we took this evidence seriously there would be radical changes made in science teaching.

We need to rethink the process or critical thinking objectives of science teaching in terms of their validity and methods by which they may be applied more effectively in helping students come to a better understanding of the basic concepts of science. We need to reexamine the conceptual structure of science and identify the basic concepts. We need to design and use evaluation instruments that measure achievement in understanding scientific concepts and in using the processes of scientific thinking.

Basically, we need to be more concerned about the ways in which all young people are going to be different as a result of their science experiences in the curriculums which we build. They should attain not only a better comprehension of the conceptual schemes which scientists have developed in their magnificent efforts to explain natural phenomena but also a better understanding of how these concepts have affected the personal, social, economic, and political lives of people. They should develop not only a better understanding of the processes of inquiry as used by the scientist but greater competence in using this process of inquiry, and consequently becoming more self-directive in their learning. Finally, they should become motivated, in higher proportions than is currently the case, to sustain intellectual interests after their formal schooling is completed.

Influence of Society

In the last chapter of the Sixtieth Yearbook of the National Society for the Study of Education,[5] Dr. Ralph W. Tyler summarizes the earlier chapters in the Yearbook having to do with social forces influencing American education. In pointing up the interrelatedness of the political system and education, he states:

---

[5] National Society for the Study of Education. Sixtieth Yearbook: *Social Forces Influencing American Education*, Part II. Chicago: University of Chicago Press, 1961.

> The survival of our political system requires educated citizens and specialized personnel, not simply trained in the knowledge of the past, but adequate to the current rapidly developing world situation. Hence the political system must for its survival press the educational system to change. Schooling will have to become an introduction to learning-how-to-learn, so that intellectual interests can be sustained through life.
>
> . . . The political system can properly demand of the educational system that the schools teach the basic skills and knowledge essential to function in a free society; that they transmit the general knowledge that comprises the cultural tradition of the civilization and the specific knowledge that is necessary to function as a member of the society and as a citizen of that political system; and that they develop skills in problem solving and in learning-how-to-learn.

It is imperative that science in American schools, along with other subjects in the K to 12 sequence, fulfill the demand of a free society for citizen graduates who are not only motivated to continue their intellectual development but possess the essential skills. It would seem to me that our progress toward this as a central purpose of education for all young people has been less clearly demonstrated than has our progress toward meeting the needs for scientific manpower.

I would recommend the reexamination of the points of view and recommendations of such science improvement projects as were carried on by the Bureau of Educational Research in Science[6] and the Eight-Year Study.[7] These projects were more clearly oriented toward the personal-social implications of science than appear to be reflected in most of the current science improvement projects. The earlier projects were concerned with ways in which science could be used to change the behavior of young people in personally satisfying and socially desirable ways. They were concerned with the scientific literacy of all young people. It was indeed unfortunate that the points of view represented by these programs were not as extensively applied nor as intensively tested as hopefully the current developments will be.

---

[6] Samuel R. Powers. "The Work of the Bureau of Educational Research in Science." *School Science and Mathematics*, 41:7–9, January 1941.

[7] Wilford M. Aikin. *The Story of the Eight-Year Study*. New York: Harper & Bros., 1942.

Progressive Education Association. *Science in General Education*. New York: D. Appleton-Century Co., 1938.

Improvement Projects

The December 1961 issue of *Science Education News*[8] was given over to brief reports on science improvement projects that have been undertaken during the past several years with major financial support from the National Science Foundation, Ford, and Carnegie. Two projects in elementary science (University of Illinois, Urbana; and University of California, Berkeley) and four in secondary school science (Biological Science Curriculum Study, University of Colorado, Boulder; Chemical Bond Approach Project, Earlham College, Richmond, Ind.; Physical Science Study Committee, Educational Services, Inc., 164 Main St., Watertown 72, Mass.; and Chemical Education Material Study, Harvey Mudd College, Claremont, Calif.) are probably best known nationally. In back of the elementary science projects was the feeling that the present courses of study, textbooks, and other materials in elementary science do not reveal adequately the methods and goals of basic science. The secondary school science studies were motivated by a concern regarding the fragmentary, descriptive, and technological nature of the conventional high school courses in biology, chemistry, and physics. The studies were designed to reduce each science field to its basic structural concepts and to develop materials for teachers and students to use in the schools. Scientists have played a major role in the development of these projects.

In several ways these projects represent breakthroughs in the development of materials and courses. Rather than merely revising present courses or working over classical learning activities, as had often been done in the past, each project took a fresh new look at what should be taught and how it should be taught from a scientist's point of view. Rather than merely developing point-of-view statements, lists of objectives, and generalized guidelines for curriculum workers and teachers, each project got down to the extremely difficult and time-consuming task of developing specific learning experiences for teachers to use with their students. Rather than merely assuming that these learning experiences were suitable, extensive programs were instituted for trying them out in schools and using the evidence thus obtained as basis for making revisions. Rather than assuming that the dated and variable subject matter preparation of teachers and the teaching methods which they had learned to use could somehow see the teachers through the new courses, they developed intensive programs for the reeducation of teachers to do the specific tasks which the new courses demanded.

---

[8] *Science Education News*, December 1961. Published Quarterly by the American Association for the Advancement of Science, 1515 Massachusetts Avenue NW., Washington 5, D.C.

From what I have seen of these science improvement projects, they represent still other worthy breakthroughs in the development of materials for instruction. To the fact-happy teacher and testmaker they have clearly demonstrated the relative significance of science facts and major scientific concepts in teaching for an understanding of science. To the ground-covering teacher and testmaker they have effectively documented the significance of pupil involvement in processes leading to concept formation and an understanding of the methods of scientific inquiry.

Three Matters of Concern

There are three matters regarding these science improvement projects which give me some concern. First, I am concerned about their exclusive commitment to basic science. It would seem that many of the proponents are more strongly antitechnology than probasic in their passion to be "pure." This may be a natural reaction to science courses, both at the elementary and secondary school levels, that had become almost exclusively applied science with only descriptive and empirical explanations. As a science educator who lived through the exciting ferment of the 1930's, my thinking about science teaching has been both stimulated and challenged by these reactionary or radical purists. I am not ready to write them off. Neither am I prepared to write off either the idea that science should make a difference in the lives of young people or the convincing evidence that the manmade environment of such phenomena as spaceships is in many ways more challenging to young people than phenomena more exclusively categorized as the natural environment. To deal with science unrelated to or insulated from the lives of young people would leave much to be desired. To deal with science exclusively from a consumer point of view would be equally disastrous. For the masses of students we must have both. As Shamos[9] has pointed out, we should help the student distinguish between the basic and the applied science whenever and wherever we deal with both; we should not leave the misconception that technology and science are synonymous.

The second matter related to the science improvement projects is a concern about the extent to which the new secondary school courses are adaptable to the ability, interests, and needs of all students in the high schools. Answers to this one will be coming from field tests in schools.

---

[9] Morris H. Shamos. "Science and Common Sense." Speech delivered at the Tenth Annual Convention of the National Science Teachers Association, San Francisco, Mar. 11, 1962.

Not unrelated to this question at the high school level is the ferment that is beginning to effervesce regarding science courses for nonscience majors at the undergraduate college level. One type of reaction is represented by this news release:

> The science requirements for college undergraduates who are not majoring in science were sharply attacked last week at a national conference of 30 scholars at Michigan State University, Oakland Branch, in Rochester, Mich. The experts recommended that every college student, regardless of major, should be required to take at least 2 full years of "hard-hitting" science courses.
>
> The "hard-hitting" label was used in opposition to special "separate but unequal" courses often devised specifically for nonscience students. The conferees thus rejected such courses that were advocated and made nationally popular by the report, "General Education in a Free Society," published by Harvard University in 1956. A Harvard scholar, Dr. Gerald Houlton, professor of physics, led the attack on easier courses "about science" for nonscience undergraduates.
>
> Dr. Alan T. Waterman, Director of the National Science Foundation, urged the colleges to learn from the lesson of the countrywide reforms that are currently improving the high-school science curriculum.
>
> "It would be interesting to see what would result from a similar attack in depth upon the problem of a suitable science curriculum for the [college] nonscience major," he said. Several conferees urged the Science Foundation to support smaller local projects to prepare new course structures, prior to any such comprehensive national programs.[10]

Statements such as the one quoted above indicate that there is much unfinished business when it comes to answering the question regarding what should be the nature of science courses for the citizen who is not planning a career closely allied with science. Some of us were foolish in assuming that we had this one answered 30 years ago.[11] I hope that those who are working up the answers now will not make the same untenable assumption.

The third matter related to the current improvement projects is a question of how these efforts will be incorporated into a K to 12 developmental sequence in the schools. Neither of the two elementary science projects referred to earlier deals with an overall elementary science curriculum. However, the learning materials developed in these projects are being tried out at each of several grade levels as a means of determining possible grade placement. None of the new high school science courses has been conceived within a developmental sequence, even at the high school level. Furthermore, there has been no major study of what the nature of the sequence should be at the junior high school level.

Several proposals for studies of sequence have been made, and I am presently associated with the development of two new ones. Studies of this magnitude will be charting relatively unexplored territory for the crews that must be involved. Even though some of the K to 12 territory has been charted before, the new crews will find it desirable to begin afresh. It is quite probable that several routes may be charted, depending upon the number of different crews who undertake the voyage. However many it may be, it is extremely important that some clearly defined purpose or objective be identified and that plans be made early in the various studies to evaluate relative progress toward their achievement.

---

[10] *The New York Times*, Sunday, June 3, 1962.

[11] National Society for the Study of Education. Thirty-first Yearbook: *Program for Teaching Science*, Part I. Chicago: University of Chicago Press, 1932.

Need for a Pattern

It would seem that we have now reached a place where the "cut-and-fit" approach to curriculum development in science needs a pattern to follow. We need to design and try out several K to 12 curriculum patterns so that the parts that have already been cut and new ones yet to be cut can be fitted into a rational whole. Some may hold that the basic design of this pattern should be uniform for all American schools. Others may contend that a minimum uniform basic design should be developed and that local communities and the various States modify as they see fit. Still others believe that several "good" patterns should be developed and tested in the schools. The relative success of the various patterns should be evaluated. Based upon evidence obtained in this way, schools should be free to adopt whichever pattern best fits their needs in terms of the evidence. Regardless of which of these or any other plan you may support, it is imperative that we develop some rational designs and test them under conditions which permit objective comparison.

Those who, within the recallable past, have worked upon a K to 6, K to 9, or K to 12 curriculum in science can appreciate what a production it is merely to get some ideas on paper. The job becomes increasingly complex to get teachers to try it out and submit reactions. It will be a monumental undertaking to develop evaluation instruments and design a study to determine objectively the relative success of several K to 12 curriculum patterns. But it must be done before we can ever begin to make defensible decisions based upon experimental evidence.

Teacher Preparation

There are two primary implications of the present great national interest in science and the improvement of our scientific effort. One is to get on with the job of building K to 12 science curriculums for the schools which not only have a scientifically rational sequence but are developmental in terms of concept and process goals based upon the needs, interests, abilities, and visions of all young people at each succeeding grade level. The second is to prepare teachers to do the job that will be demanded by the new curriculums, for ultimately it is the teacher who will make the difference.

The preparation of science teachers must begin in the high school. It must begin with science teachers who are interested in science teaching and who zealously proselyte their very best students for science teaching. It must continue into the college where special attention is given to "feeding and fanning" the convert through courses and other experiences which have been tailormade for the future science teacher. Upon his being graduated, the college which spawned the "fry" and the school in whose "waters" he finds himself must work together in helping him find his way.

In Hurd's[12] excellent article on the education of biology teachers, he is highly critical of the conglomerate nature of college programs of science study for prospective science teachers. He also questions the effectiveness of general courses in methods of teaching as preparation for science teaching. He recommends the eight guidelines as presented in the joint report of the American Association for the Advancement of Science (AAAS) and the National Association of State Directors of Teacher Education and Certification (NASDTEC)[13] as a beginning point for institutions of higher learning where faculties are truly interested in improving their patterns of education for high school science teachers.

Until colleges and universities redesign or overhaul their teacher education programs, there will continue to be great need for the inservice education of science teachers. In each of the course improvement projects referred to earlier, the inservice preparation of teachers has been a major part of the project. To date, institutes sponsored by the National Science Foundation to upgrade and update the science backgrounds of teachers have enrolled a total of more than 30,000 science teachers. Many science teachers have attended several different institutes. There is little question but what these institutes have had an impact upon science teaching. However, the extensiveness of the impact is yet to be evaluated on any broad base.

Gruber[14] conducted a study of 55 high school science and mathematics teachers who attended an academic year institute during 1957–58 at the University of Colorado. He found that the program's main weakness was its failure to transmit attitudes and information relevant to teaching science, not as a body of knowledge, but as a way of thinking.

---

[12] Paul DeH. Hurd. "The Education of Secondary School Biology Teachers." *Biological Science Curriculum Study (BSCS) Newsletter*, 13 : 7–10, May 1962.

[13] National Association of State Directors of Teacher Education and Certification (NASDTEC) and American Association for the Advancement of Science (AAAS). *Guidelines for Preparation Programs of Teachers of Secondary School Science and Mathematics.* Washington : the Association, 1961.

[14] Howard E. Gruber. "Science Teachers and the Scientific Attitude: An Appraisal of an Academic Year Institute." *Science*, 132 : 467–468, Aug. 19, 1960.

The planning of institutes for science teachers has largely been the responsibility of college scientists based upon their limited conception of what high school science teachers need. It would seem more appropriate that institutes be planned cooperatively by the people from the schools where the needs exist and people from the college or university that has the potential resources for meeting the need. Furthermore, the effectiveness of the unique institutes thus developed could be evaluated in terms of measured changes that took place in the schools. I believe that such a cooperative attack upon the problem at the State level would pay high dividends.

II. Science in the Curriculum

Earth Science in the Curriculum

Robert C. Stephenson

Executive Director
American Geological Institute

TODAY THE EARTH is being rediscovered by scientists who are finding the complex and tantalizing unsolved scientific problems of the earth a match for the most sophisticated levels of instrumentation and thinking which scientific minds are currently able to marshal. Natural scientists of the 19th century were tremendously interested in the phenomena of the environment in which they lived, and these men, through their observations and investigations, laid the foundation for the development of modern science. Within the past decade, however, there has been a rebirth of scientific interest in the earth and its environs which has grown out of new understandings of the basic concepts of science and out of rapidly developing and varied kinds of instrumentation which open the door to more exacting research studies of earth phenomena. The roots of this renaissance of earth science are found in the era of intensive geological and geophysical exploration for mineral resources during and following World War II. Additional impetus has subsequently come from nuclear developments, the International Geophysical Year, and the advent of the space age.

Just as the study of the earth by scientists has gone through a cycle, the study of earth science in the school classroom has also gone through a cycle and is now on the crest of a growing wave of interest in school science curriculums across the Nation.

At the turn of the century, geology or physical geography was one of the more common science offerings in the high schools, but as biology and general science emerged, this course of study all but disappeared from school science programs across the land. Sputnik I has been widely used as the datum of reference of the science education revolution in the United States. It is significant to point out that New York State was well on its way toward a statewide earth science course when the Russians lofted the first manmade satellite. New

York State had experimented with the course and adopted its first earth science syllabus [1] by 1955.

Science educators and scientists were watching the New York effort with a great deal of interest, so that when the Pennsylvania *Teaching Guide for the Earth and Space Science Course* [2] appeared in 1959, some States had already started introducing new earth science materials into science offerings at various levels.

The Pennsylvania earth-space teaching guide was developed by a group of geologists, astronomers, and meteorologists working with the Pennsylvania Department of Public Instruction. Because of the active participation of qualified scientists in its preparation, the guide set a new standard of subject matter content. Special recognition for the development of the earth-space teaching guide should be given to Dr. Clarence H. Boehm of the Pennsylvania Department of Public Instruction and to Dr. John H. Moss, Department of Geology, Franklin and Marshall College, who served as chairman of the Advisory Committee.

The introduction of the earth-space science course in Pennsylvania served as the detonator for an explosive development of earth science in schools across the Nation. A survey conducted 1 year ago by a major book publisher indicated that 24 States had or were planning earth science courses or units, mostly at the ninth-grade level. Perhaps today there are even more. Certainly there are many local school systems or county units which have instituted earth science courses without reference to a statewide program.

What Is Earth Science?

It is difficult to find earth science defined. Two of the major secondary school earth science texts fail to define it in accompanying glossaries. It has not been defined in the *Geology and Earth Sciences Sourcebook*.[3] Only in the newest edition of Webster (3d unabridged) is earth science defined, and then as follows: "A science (geology, geography, geophysics, geomorphology, geochemistry, meteorology, or oceanography) that deals with the earth or one or more of its parts, often used in the plural." With all due respect to the authoritative source in which this definition occurs, it is poorly conceived, and it is not completely compatible with the commonly held concept of scientists in general.

---

[1] New York State Education Department. *Earth Science Syllabus* and *Earth Science Handbook*. Albany, N.Y.: the Department, 1955 and 1961, respectively.

[2] Pennsylvania Department of Public Instruction. *Teaching Guide for the Earth and Space Science Course*. Harrisburg, Pa.: the Department, 1959.

[3] Robert L. Heller, ed. *Geology and Earth Sciences Sourcebook for Elementary and Secondary Schools*. New York: Holt, Rinehart & Winston, 1962.

Earth science deals with the scientific phenomena of the earth and its environs in space and is composed of a family of interrelated fields of science including geology, geophysics, oceanography, meteorology, and astronomy. Earth science deals with a scientific system composed of the lithosphere, hydrosphere, atmosphere, and space. The tools and rules of chemistry, physics, and mathematics are essential to the study of the earth sciences.

Why Teach Earth Science?

The earth sciences contribute greatly to the understanding of the physical and biological environment of man. If education people are to deal with the broad social and economic problems of their environment, they must understand the underlying and controlling factors. Burgeoning population, rising standards of living, and dwindling nonrenewable resources are three trends which appear to be on a collision course. Future generations are going to feel the impact of the collision of these trends, and they must be equipped with adequate basic scientific understanding to deal intelligently with the problems.

There is another facet to earth science which should be more fully developed in the education of our population. There are esthetic qualities in many phenomena of geology, meteorology, and astronomy, the enjoyment of which can be enhanced by an understanding of the underlying scientific concepts.

The study of the earth sciences affords excellent opportunities to discipline the mind. Rarely do phenomena of the earth sciences fit into tidy little boxes; so to investigate them and to understand them, one must develop an intuitive ability for arriving at reasonable answers with limited factual information. Although our body of scientific knowledge and our instruments of measurement with which to attack problems of the earth sciences have been greatly improved in recent years, this approach is still vitally important. Thinking geologically, for example, involves not only consideration of three-dimensional models, but in most instances a complicating and often frustrating fourth dimension—geologic time.

This training of the mind that study of the earth sciences affords can be valuable in the development of the reasoning abilities of any intelligent, educated person, so that study of the concepts and phenomena of earth science can play a significant role in the intellectual development of any individual.

Grade Levels for Earth Science

Earth science subject matter can be introduced into school science programs at all stages from K through 12.

A great deal of factual, introductory material about the earth and the solar system can be effectively and successfully taught in elementary school classrooms. Children are eager to learn about their environment. Many a fourth-grader has a better knowledge of elementary astronomy than does the average adult. Rock, mineral, and fossil collecting is an avid pursuit of many boys and girls of elementary school age. At the elementary school level, however, comprehension of earth science as an integrated body of knowledge is beyond the capabilities of most students.

The ninth grade appears to be the ideal level for the introduction of a full course in earth science. There are several rather apparent reasons for this:

1. Revised science curriculums have pushed the general science type of course downward into the elementary grades leaving a gap at the ninth-grade level to be filled by a more sophisticated science course.
2. Most students, by the time they have reached the ninth-grade level, have acquired the necessary reading ability required for the amount of reading needed to master basic earth science subject matter.
3. Earth science taught by well-prepared teachers can serve to illustrate the interdependence of the various basic sciences in the study of scientific concepts and processes of the earth and its environs.
4. A rigorous earth science course can stimulate interest of students in methods of scientific inquiry and investigation essential to successful mastery of subsequent basic science courses.

Earth science is being introduced in some States as a semester course at various grade levels from 7 to 10, or as short units in general or physical science courses. At the best, such a cursory treatment of the vast amount of subject matter involved will be shallow and generalized. Such courses will not contribute greatly to the scientific education of college-oriented students and may be a waste of time except as a watered-down terminal science course for students of less than college capability.

In some school systems, a 12th-grade course in geology or one of the other earth sciences may be offered to students who have completed courses in biology, chemistry, and physics. Such courses can be of college caliber.

Subject Matter

There is a need to consider the sequential nature of earth science subject matter. For example, much of what is now taught in beginning geology courses in college is not beyond the comprehension of upper elementary school children. Certainly many basic facts of geology and elementary information concerning the classification of rocks, minerals, and fossils are not beyond the reach of the average elementary school student.

At the ninth-grade level, emphasis should be on concepts and problems rather than the assimiliation of predigested facts. The *Geology and Earth Sciences Sourcebook* stresses concepts and devotes considerable attention to unsolved geologic problems. There are many opportunities to introduce mathematics, biology, chemistry, and physics in the teaching of earth science, and greater effort should be made to do so. Ideally the ninth-grade earth science course should include a solid laboratory program. The course will be most effective if it includes field trips and classroom instruction relating to actual phenomena of the immediate geographic area. The balance between the various subject matter areas may vary from course to course. In Pennsylvania the following balance is suggested:

	Weeks
Introduction	2
The Changing Earth	11
The Earth in Space	9
Weather and Climate	9
The Oceans	2

There are abundant opportunities for independent reading and investigation for the advanced student.

Secondary school earth science texts currently available are for the most part quite traditional in their approach. There is a need for a great deal of imaginative creative effort on the part of earth scientists to raise the level of earth science subject matter to the level of the ability of the students taking the course.

Teaching Resources

Since earth science has not been taught in most schools over the past several decades, there has not been very great incentive for the development of various kinds of learning aids. With the rapid development of interest in earth science, the need for organized teaching resources is one of the greatest current needs.

There should be a new look at textbook requirements in the field. This is due in part to the rapid scientific developments in the area of the earth sciences and in part to the new level of sophistication in secondary school science as a result of the massive course improvement efforts of the past several years. Needed also are teachers' guides, laboratory manuals, laboratory and classroom experimentation and demonstration equipment, and audiovisual learning aids. Again, it should be pointed out that the task is formidable because it involves to a large extent the development of new materials inasmuch as there is no "old earth science" to be revamped.

The problem of teaching earth science is immediate and the generation of new materials will take time; so existing teacher resources, such as they are, must be marshaled and used to the fullest extent. Earth science texts[4] can be augmented by various other publications[5] designed to provide additional guidance for teachers. There is no integrated series of teaching films covering the earth sciences, but the *Directory of Geoscience Films*[6] provides an annotated listing of over 500 films relating to earth science, some of which are excellent for educational purposes.

Educational materials in the earth sciences are provided by scientific societies, including the American Astronomical Society, the American Geological Institute, the American Meteorological Society, the Committee on Oceanography, and the National Aerospace Education Council. The *Geology Reference Series*[7] of the American Geological Institute lists State geological surveys from which low-cost or free educational materials relating to geology may be obtained. Educational aids are available from various Government agencies, as, for example, the pamphlet *Project Ideas in the Earth Sciences*[8] available from the U.S. Geological Survey.

One of the big problems that is plaguing those concerned with the administration of earth science courses is the fact that the available teaching resources are so widely scattered. Another serious problem is that of distinguishing the good teaching resource materials in the area of the earth sciences. A considerable amount of mediocre to poor equipment and supplies is flooding the market from suppliers who are rushing to get on the newly created bandwagon. There is considerable concern that schools will be encouraged to load up on these inferior materials only to find them useless, particularly as more scientifically acceptable resources are developed. Guidance and assistance of scientists from the various areas of the earth sciences could be utilized to good advantage to minimize such problems.

---

[4] Gustav L. Fletcher *and* C. W. Wolfe. *Earth Science.* Boston: D. C. Heath & Co., 1959.

Samuel N. Namowitz *and* Donald B. Stone. *Earth Science—The World We Live In.* New York: D. Van Norstrand Co., 1960.

William L. Ramsey *and* Raymond E. Burckley. *Modern Earth Science.* New York: Holt, Rinehart & Winston, Inc., 1961.

Frederick E. Trinklein *and* Charles M. Huffer. *Modern Space Science.* New York: Holt, Rinehart & Winston, Inc., 1961.

[5] Robert L. Heller. *Op. cit.*

Wade Linder *and* Roland B. Bartholomew. *A Teaching Guide for Earth Science Teachers* (tentative). Palo Alto, Calif.: Palo Alto Unified School District, 1960.

New York State Education Department, *op. cit.*

Pennsylvania Department of Public Instruction, *op. cit.*

[6] Wakefield Dort, Jr. *Directory of Geoscience Films.* Washington: American Geological Institute, 1962.

[7] American Geological Institute. *Geology Reference Series for Science Teachers.* Washington: the Institute, 1961.

[8] U.S. Geological Survey. *Project Ideas in the Earth Sciences.* Washington: the Survey, 1961.

Teacher Training

Teacher training is probably the greatest problem facing the successful adoption of earth science in the secondary school science program. Both New York State and Pennsylvania have found this to be the case. At least one publication contains recommendations for the preparation of teachers of earth-space science.[9] It suggests that the well trained teacher of earth science have a basic background in biology, chemistry, and physics, with superimposed courses in the various earth sciences—astronomy, meteorology, and geology. This preparation is ideal but not completely realistic, since such depth in scientific subject matter is not possible during normal teacher training. A graduate with a degree in one of the earth sciences is likely to approach this depth of subject matter, but he will be deficient in education courses. It is not likely, however, that graduates from schools of education will have the opportunity to acquire such depth in subject matter. It appears, therefore, that science graduates offer the best alternative for filling the needs for earth science teachers.

There is the problem of training existing science teachers to teach courses in earth science. This is a problem of considerable magnitude. Teachers of biology, chemistry, and physics may be perfectly competent in their own field of science and be quite incompetent in the earth sciences. Very few will have had training in oceanography and not many will have had a course in meteorology or geology. Without basic background these teachers cannot be expected to discriminate in all instances between good earth science and bad earth science.

NSF-sponsored summer institutes, academic year institutes, and inservice institutes have provided training for some teachers in the area of the earth sciences, but these earth science institutes have been far too few to meet the demand. Much of the blame for this can be attributed to the apathy of geology-geophysics departments with regard to this problem of teacher training. The apathy is due at least in part to the fact that earth science is in reality a family of related sciences, and few colleges have integrated departments embracing all facets of earth sciences.

---

[9] National Association of State Directors of Teacher Education and Certification *and* American Association for the Advancement of Science. *Guidelines for Preparation Programs of Teachers of Secondary School Science and Mathemctics.* Washington: the Association, 1961.

Teacher training will be one of the greatest problems to be overcome if earth science is to achieve its rightful place in school science programs. A great deal of concerted effort must be brought to bear on the problem. Without adequately trained teachers, the earth science course could be introduced and die off without a chance to succeed.

There must be specific programs of training designed for new teachers, and institutes or inservice programs must be greatly accelerated and improved to equip existing teachers to teach the course.

Is Earth Science Here To Stay?

In New York State, where the earth science course prototype was developed, the course has developed rapidly. Last year more than 30,000 students took earth science. In many of the New York State schools, enrollment in earth science is restricted to the upper one-third or one-fourth of the class, so it is evident that earth science is not being taught as a pushover science course for the slow learner. The problem plaguing the further expansion of earth science in New York State is that of finding a sufficient number of adequately trained teachers.

In Pennsylvania, earth-space science is taught in about 450 high schools. A testing program for the course, involving about 1,000 students, has just been concluded, and the results are being studied. Preliminary indications are that the course has been quite successful despite the lack of trained teachers.

The real answer to the question "Is earth science here to stay?" depends on how serious we are about having it stay. Much time, energy, and money will have to be invested in teaching resources and teacher training if it is to become a solid part of the school science curriculum.

Summary

Earth science is being successfully introduced into many school science programs, particularly at the ninth-grade level as in New York State and Pennsylvania. Success of the course, however, is limited by the lack of trained teachers and the inadequacy of teaching resources. Programs to provide for these basic needs are being initiated. Knowledge of earth science is vital to cultural, economic, and scientific understanding of our modern world by education people. Present generations lack understanding of the earth sciences, but the challenges posed by rising living standards, population growth, and growing nonrenewable resource demands require that future generations be trained to have a knowledge of the earth sciences essential in coping with these far-reaching problems.

Materials for Teaching Earth Science

Donald B. Stone

Instructor of Earth Science,
Mont Pleasant High School, Schenectady, N.Y.

IN THE RECENT past the education departments of several States, as well as many individual school districts across the Nation, have developed State and local earth science courses of study. Committees of teachers, along with other individuals representing interests and training in the various fields of earth science, have been officially appointed to make suggestions and recommendations, decide on goals and concepts, and finally to develop course outlines and teaching guides in the earth sciences. A major goal of these efforts is to make our secondary students more aware of the world they live in, particularly the physical earth and the space around it.

Aids for Teaching Earth Science

With the increased demand for earth science courses across the country, teachers of the subject have of necessity in many cases been drafted from general science and other subjects to take over these classes. Many of these teachers have not had the background, necessary training, or even interest to do a finished job. As a result, the subject has been dropped from the curriculum in a few areas because of a lack of properly trained teachers. This situation, fortunately, is being corrected through the many National Science Foundation summer institutes which are offering courses of teacher training in the earth sciences. It has always been my contention, however, that any good science teacher with sufficient drive and interest can teach earth science. For the benefit of those teachers who find themselves in this category, I am presenting here some teaching materials and techniques which I have found helpful over a period or more than 30 years of full-time earth science teaching.

Minerals and Rocks

One of the most difficult topics for both teacher and student seems to be the study of minerals and rocks. Often this portion of the course is completed in 2 or 3 days, largely because of a lack of training on the part of the teacher, whereas an adequate presentation of the topic may require from 10 days to 2 weeks. Class interest in minerals can be aroused by demonstrating a few chemical tests that aid in identification, such as the borax bead, blowpipe, and flame tests. A small amount of equipment borrowed from the chemistry department will prove adequate. These tests are well described in any of several books on minerals. While interest is high, each pupil should be provided with a small box of minerals which he can handle and test for himself, not chemically but for such physical properties as color, luster, streak, cleavage, fracture, and hardness. It is not unusual for students to study and examine 40 to 50 minerals, becoming familiar with their characteristics and gaining some understanding of their value. Minerals form the inorganic heart of the soils, without which there could be no life. The supply of these exhaustible, nonrenewable resources is limited, and man must become more efficient in his methods of discovery and production, development of byproducts, uses of substitutes, and methods of salvage.

Rocks should be studied following minerals, as they are often identified by their mineral content. Again each student should be provided with a set of common rocks, a lens, and perhaps a bottle of dilute hydrochloric acid. Before this work is completed, students will be bringing specimens of local rocks to the teacher for help with their identification.

Using Maps

Maps of one kind or another are helpful, and in some cases essential, in presenting a particular topic throughout the teaching of earth science. Probably the most commonly used map is the wall map; that is, the political-physical type which shows the continental areas or portions of them. This type of map is particularly useful in showing relief of an area and in locating specific physiographic regions.

Slated or chalkboard maps are probably more useful as a teaching device in earth science than the physical wall map. Although they show only the outlines of continents and countries or States, they have one advantage: they can be written on with chalk. This makes it possible to locate, outline, or illustrate many of the main topics of the course, as well as provide an aid to daily discussions.

The chalkboard map of North America, for example, can be used to outline the source regions of the airmasses that control our weather and to indicate the usual paths or tracks these airmasses follow across the continent; to locate the centers of ice accumulation in

Canada during the Ice Age; to show direction of movement of the ice as it radiated from these centers; and to indicate where these ice sheets stopped in the United States. On the chalkboard map of Europe the location of the ice center and the ice movement during the Ice Age can similarly be shown.

The chalkboard or slated map of the United States is most helpful in outlining high and low pressure areas with their wind systems, fronts, and other weather elements. It is also useful in outlining the great physiographic regions of the country, such as the Colorado, Columbia, or Appalachian plateaus; the major mountain systems; the interior and coastal plains; and other divisions and subdivisions of the physiographic provinces. It can be used to outline the major watersheds of our great rivers; to locate the national parks and indicate their geologic importance; to locate the position of the terminal moraine and the outwash plain by tracing these deposits of the Last Glacial Period across the United States from Long Island to Puget Sound by way of the Ohio and Missouri Rivers.

In a similar way the chalkboard map of the world can be used to teach some of the broader aspects of the subject. The complicated planetary wind system with calm and pressure belts can be drawn on this map, as well as ocean currents, isotherms, and isobars. It is true that all of the above can be seen in textbook illustrations, but a pupil often better understands the problem when he can see the diagrams in the making.

Another type of map that very well illustrates a particular feature under discussion is the topographic map. These maps should be mounted on stiff cardboard, with the specific features labeled in large black letters. For example, when discussing the Mississippi Delta, have on display the four adjoining Louisiana quadrangles. With these maps matched by removing their white borders and fastening them to a large cardboard or cloth mounting, they make an excellent picture of the great delta with its passes, marshes, bays, and jetties. There are many quadrangles which can be used to illustrate various glacier features, such as drumlins, kettles, and eskers, as well as shore features. The list of both maps and features is too long to be included here.

Other Aids

Geologic models are of great help in illustrating physiographic features such as folded and domed mountains and geologic faults which have resulted from crustal movements. Inexpensive models are easily made from clay with the help of the school art department. Working models of geyser and volcanic eruptions, as well as those illustrating wells and springs, particularly artesian wells, are easily made in the science project room or the school shop.

There are many other teaching aids that the writer has accumulated through the years. Outstanding among these is a large map consisting of 110 adjoining topographic maps of New York State. These maps (with white borders removed) are matched and wallpapered to one of the classroom walls. Here in full view of the class may be seen the numerous topographic features, from meandering streams and flood plains to the many glacial deposits, that are so characteristic of the northern part of the country. On another wall is mounted the 20 or more topographic maps that comprise Long Island. Here also is shown the great terminal moraine that forms the northern part of the island from Brooklyn to Montauk Point, called locally the "shore hills," and appearing on the southern part of the island is the broad glacial outwash plain whose fertile soil makes possible the great truck farms which produce vegetables for the metropolitan area. In addition to the many glacial deposits shown, there are excellent examples of various types of shore features, such as barrier beaches, offshore bars, and lagoons.

To the above may be added some suggestions for the meteorology and astronomy portion of the year's work. Meteorological instruments mounted on the roof of the school are becoming increasingly common. These include wind direction and wind velocity indicators, rain gage, and perhaps a means of measuring the amount of sunlight intensity and the approach of a thunderstorm. A weather shelter near the classroom may contain weather recording instruments such as the barograph, thermograph, and hygrograph. Some schools may be able to obtain aircraft shortwave receivers, from which broadcasts of weather sequence reports to pilots may be heard every few minutes. Some schools are fortunate in having not only sizable telescopes but an astronomical observatory.

Values of Earth Science

It would seem there is a justification for earth science in the secondary schools. The values are many. Such a course offers a wealth of information of permanent value, from both practical and cultural points of view. Its content relates to the pupil's everyday life and surroundings. This gives reality and meaning to the work because the pupil's own observations and experiences are utilized. The value of the course to students of all levels of intelligence has proved itself many times over. It provides the pupil with an understanding of his physical environment, an appreciation of our natural resources and the great need for their conservation, and at the same time gives him an interest that often continues throughout life. Travel becomes more meaningful and enjoyable, and an understanding of the physical features of the earth is of frequent practical use in such occupations as farming, mining, forestry, and navigation. For the student who goes into college, earth science provides an introduction to geology and the other earth sciences which have become of such great importance during recent years.

Revolution in Biology[1]

H. Bentley Glass

Professor of Biology, Johns Hopkins University

FOR THE PAST 4 years I have had the responsibility for the direction and guidance of the Biological Sciences Curriculum Study of the American Institute of Biological Sciences, a program undertaken to bring up to date and improve in scientific outlook the teaching of biology in the secondary schools of the United States. Although the immediate impetus and support for this program developed from the growing recognition, during and since World War II, that the military security of a nation and its rate of advance in the technology of modern civilization depend directly upon scientific discoveries, and that in turn the rate of scientific advance depends upon the level of education in the sciences, there has long been emerging a realization that something radical must be done to cope with the ever-widening disparity between education in the sciences and their actual status.

Few persons outside the sciences themselves, and the bibliographers and librarians who serve scientists, have much realization of what vast problems the exponential increase in scientific knowledge during the 20th century is bringing about. In biology, for example, the textbooks currently studied in our schools represent, for the most part, the biological knowledge of 30 years ago. To see this problem in perspective, one might note that, according to one recent estimate, the number of biological serial publications is doubling in 15 years. If our fund of biological knowledge were 4 times as great in 1930 as in 1900, then in 1960 it is 16 times what it was in 1900; and in the year 2000 it is likely that it will be 100 times as great. This is none too surprising, if it is also true, to cite another estimate, that over 90 percent of all the scientists who have ever lived are living and producing now, and that the million scientists of today may increase to 20 or 30 million by the end of the present century.

---

[1] Previously printed in part in *BSCS Newsletter*, No. 9, September 1961.

Before 1900

Another perhaps more vivid way of looking at the problem is to consider what might have been found in a good textbook of 1900, compared to one of 1930 and one of today. In biology, for example, notwithstanding the very great achievements of the 19th century—the cell theory and nature of cell division, as well as the cellular basis of reproduction; the evolution theory; the germ theory of disease; and the foundations of modern physiology, plant, and animal—the textbook of 1900 would be scanty indeed in its coverage of areas of major importance. There would be nothing in it about genetics, for Mendelian heredity was not rediscovered until the year 1900. Biochemistry in its modern sense had begun only 3 years before, far too short a time for it to get into the textbooks. Eduard Buchner's classic studies on the nature of the enzymes had just begun. The first hormone was not discovered until after that year. Immunology did not exist. It was in 1900 that Karl Landsteiner discovered the blood groups; and the existence of antibodies was first made known by Emil von Behring and S. Kitasato only 10 years before. It is very unlikely that the book would have hinted that there were such things as viruses, for although D. Iwanowsky had discovered the first plant virus in 1892, animal viruses—which cause so many of our own diseases—were still unknown. Nothing was known about specific vitamins in 1900. The experimental study of the factors governing the development of the embryo was just beginning. Pavlov had yet to do his classic studies in the fields of physiology and experimental psychology—the studies of conditioned reflex behavior in the dog.

From 1900 to 1930

Thirty years later all of these studies were well advanced, and a large number of new biological sciences had sprung into being. The postulation of the chromosome theory of heredity by W. S. Sutton and Theodor Boveri, and its subsequent proof through genetic work with *Drosophila melanogaster* by Thomas Hunt Morgan, A. H. Sturtevant, H. J. Muller, and Calvin B. Bridges, constitutes one of the towering achievements of science in the 20th century. Almost equally significant was the unraveling of multifactorial inheritance and the application of this to hybrid vigor by E. M. East and G. H. Shull. This development led directly to the production of hybrid corn, a truly magnificent contribution to agricultural productivity.

Another area of outstanding achievement in these first 30 years of the present century lay in the field of nutrition, where early adumbrations that food substances besides protein, fat, and carbohydrate were required for a complete, health-promoting diet led to the discovery of the vitamins. The investigations of F. G. Hopkins, C. Funk, and E. V. McCollum were but the most outstanding of a host of researches that elucidated the nature of vitamin A, thiamin, riboflavin, vitamin C, vitamin D, vitamin E, and nicotinic acid, and ascertained the deficiency diseases each of them corrected.

In the study of disease and resistance to disease, great progress was made. Animal viruses were discovered, and in 1918 d'Herelle added the bacteriophages, or bacterial viruses. Antigen-antibody relations were intensively explored, and a whole new field of immunology developed.

Other unexpected discoveries had been made. In 1927 Hermann J. Muller and Louis J. Stadler had independently discovered that high energy radiations such as X-rays will produce mutations in the genes of animals and plants and thereby placed in the hands of man a really formidable power to alter the agents of heredity. In that same year G. D. Karpechenko achieved the creation of the first artificial new species created by the hands of man, by utilizing a method which Nature itself has employed in the origination of many of our most important cultivated plant species: cottons, wheats, tobacco, and others. In these same years R. A. Fisher, J. B. S. Haldane, and Sewall Wright laid the theoretical foundations of a new development of evolutionary theory, based on genetics, susceptible of experimental testing, and adding to the methods whereby man can modify genes, select new types, and create new forms of life on the earth—and giving him also the power to meddle, wisely or unwisely, even with his own hereditary nature. Also during the 1920's, Hans Spemann's experiments were disclosing some of the remarkable elements in the control of the development of the animal embryo, especially the action of the organizer responsible for the induction of the nervous system in its characteristic location. Similarly, new insight into the factors controlling plant growth came with the discovery in those years by P. Boysen-Jensen and Frits Went of the growth-accelerating substances in plants, the auxins.

From 1930 to the Present

Now consider the past three decades of progress in biology. In spite of the interference with biological research caused by World War II, the advance has been almost incredible. During these years we have learned how to induce mutations with a great variety of chemical agents, through pioneer work by J. A. Rapoport in the U.S.S.R., Charlotte Auerbach in Scotland, and F. Oehlkers in Germany. Especially significant is the indication that certain agents, unlike ionizing radiations, may be used to produce only characteristic types of mutations, and hence that by means of the study of directed mutations we may analyze further the structure of the hereditary material itself.

It was during this period that the study of the transformations of *Pneumococcus* cells by material extracted from cells of a different genetic strain proved that the hereditary material in bacteria is deoxyribose nucleic acid (DNA). Another classic experiment demonstrated that for the phage-infecting *Escherichia coli*, only DNA is injected into the host bacterium, while virtually all protein remains outside. This evidence radically shifted the previous opinion that regarded protein as the replicating material basic to the nature of heredity and reproduction. Also in the 1950's came the fruitful theory of J. D. Watson and F. H. Crick regarding the structure of the DNA molecule and its method of replication. The famous hypothesis of the double helix with its paired purine and pyrimidine bases has led to much vigorous investigation devoted to the problem of how DNA passes information to RNA (ribose nucleic acid), and how the latter in turn specifies the amino acid structure of protein or polypeptide chains.

Arthur Kornberg has shown that it is possible to take from the common human intestinal bacillus *E. coli*, an enzyme that, when provided in a test tube with the four fundamental kinds of nucleotide triphosphates and a bit of native deoxyribose nucleic acid (DNA) extracted from some living cell, will synthesize an abundance of new DNA, of the same kind as the primer or model DNA put into the system. This is the first essential step in the artificial creation, by man, of genes.

Marshall Nirenberg and Severo Ochoa, working independently, have in 1961 "cracked the genetic code" and carried to completion a scientific investigation analogous to the deciphering of Egyptian hieroglyphics, Babylonian cuneiform, or Minoan B. That is to say, they have determined the composition of the 21 nucleotide triplets in ribose nucleic acid which convey the genetic information from the DNA to the protein-synthesizing centers of the cell, and there specify which of the 21 usual amino acids is to be inserted, in its proper position, in the protein molecule being synthesized. Frederick Sanger has used a most amazing type of analysis to dissect, by means of proteolytic enzymes, the entire protein molecule of insulin, to identify its 51 amino acids, and to map the entire sequence of these within the molecule. Already since that work several more protein molecules have been completely "fingerprinted" in a similar way.

The number of vitamins formerly known has rapidly increased during these 30 years—folic acid, vitamin B_{12}, pyridoxine, nicotinamide, and others—and, what is of greater importance, we have learned something more significant about them than that they are required in the human diet. We have learned that vitamins are commonly incorporated into coenzymes each of which plays an essential, very specific, role in the chemical machinery of life. It was during the 1940's that Fritz Lipmann first pointed out the remarkable nature and functions of adenosine triphosphate, or ATP. Today we can scarcely conceive how it was ever possible to talk about human metabolism, or the use of energy in any plant or animal or microbe, without a knowledge of the role of this substance. Vincent du Vigneaud has shown how to synthesize some of the polypeptide hormones produced by the pituitary gland, the first hormones actually to be synthesized. A. Butenandt, Edward A. Doisy, E. C. Kendall, and other workers have worked on the steroid hormones of the adrenal cortex and gonads, and found the way to synthesize them artificially. Out of these investigations came the remarkable studies of the physiological action of cortisone, of ACTH, and of the sex hormones.

During these years, the efficacy of the sulfonamide drugs was discovered. Sulfanilamide had been known for decades as a chemical product, for which no special use had been found. Now it was first tried out as an antibacterial agent, and proved to be tremendously effective against many different kinds of bacteria, since it competes metabolically with a certain coenzyme (paraminobenzoic acid) necessary to the microbial organism. Antibiotics were discovered in this same period: penicillin, streptomycin, aureomycin, and a host of others. It is already hard to think back to the time when we didn't have this armamentarium of antibiotics able to banish infectious disease almost completely, if we but use them wisely. Nor should we forget the development of the new insecticides, the most widely known of which is DDT, enabling a vastly greater control over typhus fever, malaria, and flyborne diseases to be introduced. The effective control of many pests has likewise been improved, and agriculture has benefited tremendously.

The introduction of the electron microscope and the phase microscope during these years has led to a resurgence of morphological studies of cell structure and process. We may now hope to tie together the biochemistry and the ultrastructure of the cell. Especially promising in this respect are studies of the chloroplasts, throwing new light on photosynthesis, and of the mitochondria, illuminating the basis of respiration. We may locate Hans Kreb's citric acid cycle, discovered in the 1930's, in the latter; we may place the steps in CO_2 fixation, worked out by Melvin Calvin, and of photosynthetic phosphorylation, discovered by Daniel Arnon, all in the years of this last decade, in the former. For the first time, too, we can now visualize from photographs the structure of the viruses, and even photograph the single large DNA molecule found to constitute the entire hereditary material of some of the bacteriophages, or bacterial viruses.

In these same 30 years, Wendell Stanley succeeded in extracting enough tobacco mosaic virus from infected tobacco leaves to crystallize it. The studies of the properties and effects of pure virus threw new light on the borderland between living organisms and the inorganic world.

Some of the discoveries made in this most recent 30-year period might seem to be purely of academic interest; for example, the discovery by Joshua Lederberg and Edward L. Tatum that bacteria have sex, and will mate if you get the right sorts together. Yet this discovery opened up the entire field of bacterial genetics, previously a mystery. It led to the discovery that bacteria have chromosomes like those of higher organisms, with genes arranged in a linear series, and that these genes govern the biochemical processes of the organism's metabolism in essentially the same way as in human beings. A large part of human biochemistry and pathology we now owe to studies made first on bacteria.

The basic analysis of this sort of study was developed earlier during these three decades in the work of George W. Beadle and E. L. Tatum on the effects of mutations in the pink bread mold, *Neurospora*. As the British physician A. E. Garrod had predicted in 1908 on the basis of certain human "inborn errors of metabolism," as he called them, Beadle and Tatum found in *Neurospora* that each individual mutation that prevented growth did so by blocking a single specific step in metabolism. Through comparison of the metabolism of mold, bacterium, and man, we now stand at the dawn of a new era in medicine. The study of infectious diseases is no longer so important as it once was. Many physicians in those countries with advanced health standards have never seen a case of malaria, typhoid fever, and other diseases that were once the scourge of mankind. But we still have our inborn errors of metabolism, the faults of our genes, and now we must begin to learn, step by step, how to ameliorate them. This can be done when we learn exactly what metabolic step is blocked in each disorder, what essential product of that step must be supplied, or what substrates, accumulated in the body through lack of normal utilization, are producing harmful effects and must be eliminated. Biochemistry and genetics have joined forces in a new type of medicine that will clearly have for the future as great a consequence as the discovery a century ago that bacteria and viruses are the agents of infectious disease.

These 30 years saw tremendous strides in the development of evolutionary studies. They advanced from a theoretical and observational basis to many kinds of experimental analysis and verification. A catalyst in this respect was the appearance in 1937 of a book entitled

Genetics and the Origin of Species by Theodosius Dobzhansky. Equally influential has been A. I. Oparin's *The Origin of Life on the Earth* (1936). The influence of these works has spread more and more widely through the biological sciences, until the dormant—some persons said moribund—Darwinism of the early 1920's has developed into a strongly knit, experimentally based science permeating all of biology. Its influence is equally clear in paleontology (G. B. Simpson's *Tempo and Mode in Evolution* and later works), in zoology (B. Rensch's *Neuere Probleme der Abstammungslehre*), and in botany (G. L. Stebbins' *Variation and Evolution in Plants*), to name but a few examples. It has given new force and direction to systematics. It has invigorated the study of anthropology and human evolution, and is partly responsible for the great current interest in the blood group systems which led to the discovery by A. C. Allison that the "harmful" gene which produces sickle hemoglobin is maintained in central African populations because it confers protection against tertian malaria, and the equally novel and exciting findings by Vernon Ingram that sickle hemoglobin, the product of a single gene difference from normal hemoglobin, differs from normal hemoglobin in a single amino acid residue in the entire molecule. Thus we learn that the gene acts by specifying the order of the amino acid groups in a protein molecule.

Space and time, and my own knowledge, fail; and a more exhaustive account of even the most outstanding biological developments of the past 30 years might lead us too far from the point to be made here: that of the exponential increase of scientific knowledge in our time. Suffice it to say that in ecology and in the study of animal behavior, in the study of populations and communities and their management, as well as in the responses of whole organisms to their environment, and in every aspect of their biology down to the biochemistry and biophysics of their ultimate atoms and molecules, there have been vast and fundamental advances of which note should be taken.

The Future

What the remainder of the century will disclose we can only guess. We can, however, be confident that our scientific information is likely to increase at the same formidable exponential rate. This raises in aggravated form the problems of its publication and dissemination, its storage and retrieval, and its transmission to the younger generation. With every year during which we fail to find a sufficient solution or even make an effort to cope with these problems, they grow more insoluble. Perhaps modern science will eventually bury itself under a mountain of paper.

Along with the practical and theoretical kinds of discoveries I have named, there has come, then, a very great increase in our insight into the kinds of problems that face man biologically in the future—an understanding of race, and of evolutionary problems that we hope will enable us to act more wisely in the future. What will biology be in the year 2000? It is rash to try to guess, for what biologist of 1930 would have dreamed then of our present knowledge and perspectives? Yet perhaps we can foresee a few directions in which our control over life will be extended.

We will probably learn, through increasing studies of the processes of aging, not only how to extend the human lifespan but also how to maintain the vigor of mature life into advanced years. I also suspect that by the end of the century biologists will have learned how to create some simple forms of living organisms, perhaps at the level of complexity of a virus. By that time, too, it should be feasible to cultivate human reproductive cells, as well as those of animals, in artificial culture media; to produce normal embryos "in vitro," as the biologist says; and then to raise them to term either in the artificial cultures or by implanting them in foster mothers. In the process, it may become possible to modify defective genes or to replace them with sound ones. More surely, before the next 40 years have passed, man will have solved the problems of photosynthesis and will have learned how to assure himself of an inexhaustible supply of food. It may not be very palatable, but biologists of the future, given time, can provide good flavor too. Man will certainly have learned to accelerate his own evolution, although I wonder what direction he will choose. Infectious diseases will very likely have been banished completely, along with hunger; but sufficient space for an uncontrolled growth of population seems out of the question on this planet, and happiness is not something that flowers inevitably from the burgeoning of science.

Problem of Science Education

Now let us return to the problem of the transmission to the next generation of the scientific heritage we have produced. Our educational system is very poorly organized to cope with the transmission of a selected core of facts, concepts, and principles from an exponentially increasing body of knowledge. In the first place, consider the teacher. The teacher of today is the student of yesterday, who passes on largely the knowledge he learned while a student. If the teacher continues in his profession for 30 or 40 years, his skill in transmitting knowledge may greatly increase, but his stock in trade is outdated by a generation or two. And this situation is aggravated because the secondary school teacher learns from a college or university teacher, who in his turn, unable fully to keep up with the development of science, is also in danger of presenting an antiquated picture of it. One does not escape this dilemma by adverting to the writers of textbooks, for they are in the same position as the rest of their university colleagues. Unless they remain avid learners throughout life, and unless they acquire rare skill in critical evaluation and synthesis, they too suffer from a horrifying rapid obsolescence.

The curriculum studies in the natural sciences are the first answer to the growing awareness of this problem. In the United States, curriculum studies are now progressing in physics, mathematics, biology, chemistry, and geology, with the support of the National Science Foundation. These curriculum study groups, for the first time in the history of American education, are doing more than merely planning, outlining, and recommending. They are actively preparing textbooks, laboratory programs, and new innovations in teaching, while engaging as wide and expert a group of scientists and teachers as may be enlisted for the purpose. The Biological Sciences Curriculum Study, after trying out its preliminary materials in 118 schools in 1960–61, set about a thorough revision of them preparatory to trials in 350 schools in 1961–62. By September of 1963, the tested textbooks and laboratory guides, with sufficient teachers' guides to assist teachers to utilize a more modern approach to biology, will be put into general production for use on a national scale. This undertaking has already aroused international interest. In the summer of 1961 we had working with us, adapting our materials for use in their countries and translating them into their own languages, representatives from the Argentine Republic, Brazil, Colombia, Thailand, and Nigeria. There have been many inquiries from other countries. These are first steps. Of course, it will remain necessary, such is the tempo of scientific advance, to revise the new books almost as soon as they have been issued.

The teachers in our schools are not at the present time trained in the basic science they need to handle such a program and to teach it well. We find that training institutes are necessary to reeducate the teachers in a knowledge of present-day science. Thus, many of those trained to teach biology do not know enough chemistry, particularly enough biochemistry, to deal with modern biology. But there is a general awakening to the need for frequent and systematic continuing education in science for those who teach it. The Summer Science Institutes begun by the National Science Foundation in the United States have been instrumental in this; and when the summer institutes are supplied with the new materials from the curriculum studies, we hope that a new level of science teaching will evolve rapidly.

Already it has become evident that, if the teaching of biology and the other sciences in the secondary schools is to proceed very effectively, there must likewise be a thoroughgoing revision of the program of science teaching in the elementary school and junior high school levels. This will be undertaken. Can we expect less of the universities? If the secondary schools teach a modern biology, for example, can the colleges and universities continue to prepare teachers and train scientists by teaching an antiquated biology? Here, too, a large-scale revision seems necessary. Is it too much to venture the guess that the time will come, perhaps in a very few decades, when each practicing scientist and every science teacher will be expected, nay, required, to spend 1 year in 3 in reeducation?

What is the main objective we should keep in mind as we undertake this formidable task? In my opinion, it is to learn and to teach the nature of science. James Harlow, Executive Director of the Frontiers of Science Foundation of Oklahoma, recently said that probably "fewer than 10 percent of the entire precollege teaching staff holds any real awareness of the basic nature of science." There are so few science teachers among all teachers, and among the science teachers themselves there are so few who have had enough of the right kind of work to get a real understanding of the nature of science. And yet, if we are going to develop a civilization that is broadly and soundly based upon a scientific foundation—and we can hardly escape that now—then the general citizen of this country, the man in the street, must learn what science truly is, and not just what science can bring about. Surely this is our primary task. If we fail in this, then within a brief period of years we may expect either nuclear devastation or worldwide tyranny. It is not safe for apes to play with atoms. Neither can men who have relinquished their birthright of scientific knowledge expect to rule themselves.

For a scientific society to be democratic, the people themselves must understand the nature of the scientific forces and problems that dominate their lives. For us who teach, this by no means signifies teaching simply a lot of facts about science, or even its important concepts and principles—that the earth is round and not flat, that the atom has energy in it, that the genes control the paths of development. All those things are important; but far more important is the comprehension by the learner of the true nature of this process whereby reliable knowledge about matter and energy increases and whereby man acquires new understanding of life and its place in the universe. Here lies our power as teachers. We can be pioneers in the effort to reorganize and reinvigorate the teaching of biology and of the other sciences and give it new direction.

Conclusion

In a living cell we find that each active chemical system consists of substrate, enzyme, coenzyme, and an energy-rich molecule, adenosine triphosphate (ATP). The teacher must play the part of an enzyme, which combines with its substrate, changes it, and then releases the altered product. The enzyme is itself renewed in the process. So the true teacher must actively combine with his substrate, the minds of the learners—his students—then cut them loose, while being himself renewed by the experience. This means never to "teach at" students, but rather always to learn with them. Where better can this be done than in the laboratory of science or the field? With the coenzyme of modern teaching materials, and with plenty of high energy, the precious product of an enlightened mind results. Of course, the cell also instructs us, as we examine the marvelous devices of the mitochondria, chloroplasts, and ribosomes, that organization to a refined degree is also requisite.

One might add: The young student can become a scientist himself, and his teacher, transcending the art of the enzyme, can become a gene, for what but a gene can replicate itself?

Newer Resources for Improving Instruction in Biology

Paul Klinge

Assistant Professor of Education
University of Indiana

IT IS A FORMIDABLE task to consider the great wealth of materials which are now in existence for the improvement of biology instruction, as well as the great number of talks, seminars, conferences, presentations, and television series which are frequently on this topic. It reminds one of the story of the traveler who stopped in an old rural store in the southern part of my State and inquired as to the quality of some Roquefort cheese which the store proprietor had for sale. He replied that the cheese was indeed for sale, but as to quality, he could only say that, "Most everything has happened to this cheese that can happen to cheese." I feel that I am in very nearly the same position in taking up a topic which has had almost everything happen to it.

Many biologists have said that a revolution is occurring in biology. The inference is that a revolution is consequently occurring in biology teaching. I should like to take mild exception to this idea, as I believe that the term "evolution" might be much more appropriate when studying the changes in the teaching of biology.

Revolution has always implied to me a sudden, drastic, and quite traumatic change which destroys many old values and ideas. I do not believe that in this semantic context the term "revolution" is applicable to the subject which I am to discuss. The term "evolution" implies change, but change which may be quite variable as to rate. Evolutionary change has deep and obvious roots in the preceding history. In other words, it is easy to trace the history of many of the changes which are now occurring in the teaching of biology.

If I may carry the dangerous game of analogy still further, it is quite obvious that the factor of natural selection will be operating in a powerful way for many of the ideas which are being proposed for the improvement of instruction of biology. Indeed, there will be a few mutations, but as the geneticist has so well proved, many of these new and startling ideas may very easily be deleterious to the total effectiveness of an improved biology teaching program.

I believe that many of the new developments which have occurred in the corpus called biology are being reflected in the teaching of the subject. But the process of natural selection will eliminate some of the characteristics of teaching which are no longer pertinent and give quite a bit of emphasis to factors which now, in our new biological environment, are of great adaptive significance for the teaching process.

Changes in Biology Reflected in Teaching

That dramatic changes and new "breakthroughs" are apparent in biological research is a well-accepted fact. But which changes have occurred in the research field which can be reflected in the teaching of biology?

In the first place, biology has become less and less of a strictly observational science and more of an experimental one. Perhaps it would be in order to define these terms, because observation is still a key concept in most biological experiments. What I really mean is that students can no longer be encouraged to picture biology as purely nature study in which one observes only the mannerisms, habitat, and general features of organisms. Observations will have to be parts of experiments which reveal more accurately other characteristics of the organism which are not readily apparent by the casual observation process that has been common in natural history approaches.

Secondly, the areas which biology has traditionally embraced have now received a completely changed proportionate emphasis in the research man's work, and this switch is reflected in our change in emphasis of the key units of the biology course. An obvious example of this is the rather dramatic decrease of emphasis on morphology and taxonomy, and the increase in emphasis on such topics as genetics, cell metabolism, evolution, and physiology. Some recently published texts and proposed courses practically eliminate the subjects of taxonomy and morphology, but I am sure that the process of natural selection will show a short life for courses which totally ignore areas which are still of fundamental importance.

Thirdly, the research biologist's new understandings of cell metabolism make it quite apparent that this must be reflected in the courses of study. This implies understanding of some chemistry and physics.

Lastly, biology has become an integral and highly important part of the total science picture. A biology teacher who ignores chemistry, physics, mathematics, or geology is seriously jeopardizing the future understanding of biology which students must have. Biology's interrelationships with all of these other sciences are now apparent and so close that these interrelationships must be reflected in the courses of biology that are being offered in our schools.

Teacher Training

Now, if biology as a science has changed, the first place which the improvement of biology instruction can get its most firm foothold will be in the training of teachers. This process of teacher training has changed gradually and will probably have quite a few more changes.

Certification patterns for biology teachers are changing in a steadily evolving fashion throughout the country. However, some major points should be emphasized. Paul Hurd[1] emphasizes that the changes which have occurred in biology must be reflected in the training of teachers in several ways. In the first place, general courses in the humanities must be an integral part of every biology teacher's education. It seems now apparent that biology teachers must have a good liberal education; a great plethora of technical courses, whether in biology or education, seems out of place. Indeed, biology and all science is more than a technical subject, and biology teaching requires more than a technical training. Another change that has occurred in certification patterns is the emphasis on other sciences in the training of biology teachers. For instance, in the State of Indiana the new certification pattern makes it very convenient for the biology teacher to take his primary certificate in biology and his secondary area in chemistry. This is to make inconvenient the former condition of biology teachers having secondary areas in physical education and health, or vice versa. The overlap in the courses required for these areas determines in most cases the type of certificate the teacher will be attempting to attain. If we maintain this insistence that other sciences be included in the training of the biology teacher, then the day of the physical education major with minimal training in biology being primarily responsible for the biology courses will be on the wane.

Dr. Hurd has pointed out another feature of biology teacher training which was new to me. He indicates that "practically no biology teacher has ever had a methods course on teaching the subject."[2] More and more, facility in the use of instruments and biological materials requires an emphasis which the colleges evidently have been unwilling to provide to date.

---

[1] Paul DeH. Hurd. "The Education of Secondary School Biology Teachers." *The American Biology Teacher*, 24:327–331, May 1962.

[2] *Ibid.*, p. 328.

Teacher training implies more than a 4-year course for certification. Inservice training of teachers has received a great deal of emphasis, and it has been supported in great measure by the National Science Foundation. The impact of these programs on the further training of existing biology teachers is tremendous and cannot be overlooked. Also, colleges and universities have come up with serious programs of their own for inservice training, and many of them have antedated the NSF programs. The master of arts for teachers degree is a considered and widespread effort on the part of universities to meet the need for good subject-matter training in the fifth-year program for biology teacher education.

Another of the efforts on the part of institutions of higher learning to help teachers is seen in invitations to high school teachers to attend seminars, discussions, and conferences which have heretofore been closed to them. For instance, we send out a weekly bulletin to some 400 teachers throughout Indiana informing them of these programs, technical though they may be, on both our main campus and the medical center campus. Attendance of teachers has gradually increased, although we have a long way to go before we can claim a satisfying percentage of attendance.

Another effort in this coordination between colleges and high schools in helping the training of high school teachers is the visiting scientists program, now quite often sponsored by NSF but initially the product of the cooperation of professional societies in their efforts to provide the services of the professional biologist to the high schools.

Less well known are the efforts of some colleges and universities, and even some industries, to encourage high school teachers to visit their campuses and installations, not for just a perfunctory tour of stainless steel and shining equipment, but for some real businesslike and instructive discussions on the part of the staff in what they are doing. This is done in the hope that these discussions will be valuable to the teacher in translating some of these ideas into classroom use.

All of these programs, aimed as they are at the teacher, constitute in my mind the most important resource by which the instructional program in biology can be improved. Any efforts which supervisors and consultants can make in stepping up these programs, encouraging teachers to participate in them, and in some cases, giving real recognition for this type of participation, will prove well worth while.

Biological Sciences Curriculum Study

The second most important facet of the improvement of biological instruction is the massive effort made by the Biological Sciences

Curriculum Study. Although the details of this operation are well known, I might remind you that it constitutes the one and only massive effort for the improvement of biological instruction. This statement is true not only in the contexts of time and money but also, in my estimation, in quality. While some of the materials which the BSCS has produced have been subject to some criticism, I do not believe that they need any apology or defense. The process of natural selection, again, will operate on them, and this is the healthy process with which biologists have learned to live. However, it does require that these materials be given an adequate and objective trial. Certainly one result will be inevitable: this will be the gradual changing of traditional courses by textbook authors, curriculum committees, and college training staffs. The general impact of the materials and their quality will inevitably be reflected in all other treatments of biology instruction.

I should like to list for you the efforts of the BSCS that are of considerable importance. The first is the three texts which have been proposed. These will shortly be published commercially for distribution in the usual commercial channels. These three texts were based on the assumption that there is no one way to "skin a cat." This one decision has been the subject of some criticism, but again, I offer no defense for it, as I am sure it will stand the test of time as to its wisdom. This textual material reflects the changing emphasis among the various units of biology. None of the three reflects or duplicates the emphasis in the traditional texts.

The laboratory materials which have been prepared for each of the texts are unique and highly experimental; they encourage the student not to use the laboratory as only a convenient place to draw, copy, and dissect. The student must make appropriate observations, do experimental work, and come up with answers which cannot be found in any text.

A really unique idea in the textual materials produced by BSCS is the so-called "block."[3] This is a series of laboratory exercises centered around one specific topic which the student will need some 6 weeks to work through. The plan is for these blocks to constitute the laboratory part of a biology course but not necessarily be related directly to what is being taken up in class. The assumption that laboratory work must be correlated and integrated completely with classwork appears quite logical but does not have a great deal of objective evidence. Biology has a problem in that organisms have a definite period of growth which cannot be hurried up to fit a 40- or 50-minute laboratory period. But if this process is extended over 6 weeks, some really fine and detailed work can be done around one specific topic. These blocks which have been produced will, I predict, become one of the most important features of the BSCS program.

---

[3] Addison E. Lee. "The Experimental Approach in Teaching Biology." *The American Biology Teacher*, 23:409–435, November 1961.

The gifted student volumes are efforts to inspire the student who is interested in doing high-class project work. The projects suggested are detailed, yet they do not give recipes. They are simply "teasers," aids, and guides for the student, but they give neither specific instructions nor all the ramifications of the projects suggested.

The monograph series, many of them of the paperback type, should be found on every biology library shelf.

Along with the materials which have been presented are also detailed teacher aids and guides. These volumes probably constitute one of the best resources for the improvement of instruction, insofar as methods, materials, facilities, and equipment are concerned, in the entire country. I certainly recommend it for your close inspection.

A final section of the BSCS activities involves the production of very short films, mostly for the illustration of techniques, which do not duplicate anything on the market to date.

The BSCS is indeed a second most important resource for the improvement of instruction. The teacher who is not reasonably well conversant with BSCS materials is simply ignoring one of his most important resources.

Other Curriculum Aids

The Science Manpower Project of Columbia University has produced a volume on the biological curriculum written by Dorothy M. Stone.[4] The publication antedates the publication of many of the BSCS materials, and it is interesting to see how well the author predicts many of the things which the BSCS eventually took up as major parts of its program.

Still another feature of curriculum studies are those produced by individual States and cities. Such curriculum aids by the city of New York and the State of New York serve as models for this process. However, other cities have done quite a bit of work, and their curriculum guides are detailed enough to be good sources of information for other cities and school corporations to use as models. I am unable to list all of these, but the efforts of Chicago, San Diego, and Los Angeles are among those worth reviewing.

---

[4] Dorothy M. Stone. *Modern High School Biology.* New York: Bureau of Publications, Teachers College, Columbia University, 1959.

Reading Resources

It is impossible to list all of the magazines, journals, paperbacks, and text materials which have appeared in the last 5 years. However, it is apparent that there are several which should be singled out for closer attention.

Among the popular magazines, there is no doubt that *The Scientific American* is a "must" item for all science teachers and, as is now apparent, for all scientists. This magazine has no peer in the range and scope of its articles and their quality. Indeed, teachers might take quite a few lessons from the way a skilled science writer or scientist is able to translate detailed and intricate findings into a palatable form for the variety of readers which *The Scientific American* enjoys.

In the field of science education journals, *The American Biology Teacher* should be a regular item of reading for any biology teacher wishing to improve his teaching. *The Science Teacher*, of course, embraces many other areas of science, but it should also be on the reading list of biology teachers. Many of the articles which it carries are specifically pertinent for the biology teacher, and many of its other articles have enough general interest to warrant their careful reading.

One of the amazing developments in the book publishing business has been the paperbacks, many of which are reprints of classics in the field and some brand-new volumes. A number of these are written specifically for biology students, and these include the Prentice-Hall series called "Foundations of Modern Biology" and the "Natural History Library" of Doubleday Co. These are but two examples of series which are being produced, and their quality is such that they are highly recommended reading.

The textbooks which are being produced for high school use are coming out in an ever-increasing quality and quantity. I am not going to review these textbooks, but I would like to focus your attention on the text material which is being prepared for college use. Some of these texts have been rather radically revised from previous college texts, so that many of them employ approaches which are unique and pertinent for the high school teacher. Especially is this true when one considers the great increase in the number of so-called advanced biology courses and those efforts on the part of teachers to give more detailed instruction in certain areas than the regular high school biology text does. I am impressed with quite a few of these new approaches, and it would be difficult to list them all here. I would like to suggest the new text by Garrett Hardin; the classic produced several years ago by Simpson, Pittindrigh, and Tiffany; the rather orthodox treatment of Johnson, Laubengayer, and Delanney; and the biochemical approach in the texts by Weisz. These are important aids for teachers because they translate many complex ideas in biology which the high school teacher then can take one translation step further for his own classroom use.

Supply Company Aids

For a great many years the General Biological Supply Co., under the title of the *Turtox Leaflets*, has produced a series of invaluable aids for biology teachers. Ward's Scientific Establishment has now entered the field, and its latest publication, *Culture Leaflets*, is its effort to aid the biology teacher in a very objective way. These two single efforts can be pointed to as indicating how the scientific suppliers can assist biology teachers in a most pertinent and striking way. The Welch Scientific Co. has for quite a few years produced its *Welch Biology and General Science Digest*, and this too is a valuable resource.

Audiovisual Aids

The lists of those which are now available constitute quite a few catalogs, and I certainly cannot list them all. One type of audiovisual aid is recordings, some of which include such things as birdcalls and other animal sounds; another recording is a rapid review of many biological principles which presumably one plays frequently so that repetition enables one to learn them. I cannot get very enthusiastic about these, but I suggest them here as a type of aid which has not received much publicity. There are also series of large color photographs on the market which are suitable for framing or bulletin board use.

The AIBS Film Series now being marketed by the McGraw-Hill Co. is a type of operation of which all science supervisors and consultants should be aware. This is a considered effort to put on film an entire course in biology in 28-minute sequences. It should be pointed out that any of these film may be purchased separately. The latest ones do not employ the unadulterated lecture method, but utilize a variety of pedagogical devices. By all means, these films should be inspected for possible use, although it must be admitted that they are uneven in quality.

Commercial producers of films have been keenly alert to the needs of the biology teacher, and I should like to point out the efforts of the Encyclopaedia Britannica Films, Coronet Films, and the Indiana University Audio-Visual Center in the production of such films. I am in no way listing all such companies, but I have singled out some whose films have received favorable reviews.

Television

A television series under the heading of "The New Biology" has been taught by Dr. Ray Koppleman of the University of Chicago. The reactions to this course have been quite varied. The use of this series for the inservice training of teachers has been proposed. Yet after viewing quite a few of the series, it seems to me that it would be quite appropriate for high school use in conjunction with a skilled high school teacher.

Facilities and Equipment

The *NDEA Purchase Guide* produced under the auspices of several organizations should be familiar to you. In my opinion it constitutes the single effort to list in a rather dull but very useful way the items and equipment necessary for the improvement of biology instruction.

The BSCS has also been in the business of doing much the same thing, and its efforts along this line should be looked at very closely, regardless of whether or not the teacher is involved in the BSCS programs.[5]

Other efforts have been made by organizations such as the Midwest Research Associates of Kansas City and the National Science Foundation in its programs of assistance in the production of new types of equipment and in the improvement of existing types. The Educational Facilities Laboratories periodically produces beautiful reviews of classroom and laboratory design. These will be quite useful to the teacher, department head, and administrator in preparing preliminary drafts of new buildings.

Methodology Textbooks

New textbooks for the college methods course, as well as for teacher use in the classroom, are appearing. The Morholt, Brandwein, and Joseph *Sourcebook*[6] is one of the finest sources of many of the ideas, techniques, and tricks of the trade which it is necessary for every teacher to have.

---

[5] Richard E. Barthelmy, Don E. Borron, *and* Addison E. Lee. *Techniques and Equipment in the Biology Teaching Laboratory.* Boulder, Colo.: BSCS, University of Colorado, 1962.

[6] Evelyn Morholt, Paul F. Brandwein, *and* Alexander Joseph. *A Sourcebook for the Biological Sciences.* New York: Harcourt, Brace & Co., 1958.

Career Pamphlets

One of the essential features of good biology teaching is to impress upon students what careers are available in the various disciplines of biology. While the book, *Career Opportunities in Biology*, published by Row-Peterson, is still a standard in this field, the lists of individual pamphlets is an extensive one indeed. Bibliographies of these have appeared in practically all of the professional science teaching journals. Some universities are now preparing their own, and professional societies are responsible for specific career pamphlets.

Professional Societies and Journals

There is no doubt in my mind that the membership of a biology teacher in professional societies will assure at least some reading of the journal which the society issues. Attendance, occasionally or regularly, at the meetings of these professional societies, as well as the reading of the journals, will constitute one of the best methods by which the instruction in biology can be improved. I believe that it is the responsibility of every science supervisor not only to encourage membership in professional societies but also to make this membership a prerequisite for advancement and professional recognition.

Curriculum Guides

I have mentioned above many of the efforts made throughout the country for the improvement and development of new curriculums in the biological sciences. This type of work by local committees of biology teachers constitutes one of the best ways in which their instructional program can be improved. The emphasis here is not the end result of the curriculum study committees, but the whole process by which the teachers work on the improvement of the biology curriculum and in so doing improve their own instructional capabilities.

Secondary School Student Programs

Three State universities initiated in 1956 programs for high school science students. Industries and Government installations also carried out similar programs on a small scale. Subsequently the National Science Foundation and other organizations have supported such programs so that they have become common features of many university campuses. Because these students are recommended by their teachers, I am submitting the idea that the return of many of these students to the high school campus constitutes a really effective way in which the high school teacher can improve his own instructional program. This is an unusual feature to be pointed out for the secondary school program, but I am convinced of its effectiveness.

What Should Be Done Next?

I think that probably the most important thing that I can say here is that there is still much to be done. Trends are steadily evolving that will be of great significance in the next 10 years for all science teachers, and especially consultants and supervisors. But what are some of our immediate needs?

The college curriculum will have to be revised to reflect those necessary changes which must be made in the training of biology teachers. The traditional approach is no longer adequate. Simply rearranging the college course structure to improve certification or to change the pattern of biology teacher training is not enough. Colleges must make a real effort toward revising their entire biological science sequence for the training of biology teachers.

Foundations which support science teaching improvement, and some foundations which assist the research side of biology when it has some educational implication, still do not give the percentage of support to the improvement of biology teaching warranted by the number of biology students in the country. The staff structure in some foundations, as well as their announced interests, seems to place the efforts of the entire biological teaching profession in a second-rate status. I must in all honesty and fairness indicate that this situation has improved considerably in the last few years, but much remains to be done.

Another pertinent point that should be made here is that, unlike the American Chemical Society or the American Institute of Physics, the many biological professional societies have been slow to form those local chapters which can provide the teacher with cooperation and assistance. (The notable exceptions to this are the local chapters of the American Society of Microbiologists.) The local chapters of the American Chemical Society have been most helpful for the improvement of science instruction, especially in chemistry, but the biologists cannot boast of a corresponding effort.

One of the unpleasant things that I must point out is that while industry has been a most effective supporter of many programs for physics, chemistry, and mathematics teachers, its support for biology teachers has been conspicuous by its relative absence. I suggest that the appropriate industries reconsider their present positions in terms of educational support.

Probably the most important thing for the future is the absolute necessity of editing our biology courses so that within the given time allotment in schools the most essential things in biology can be taught. It is no longer possible to assume that when a new discovery in biology comes to light, it can simply be added to the biology course. We must avoid the encyclopedic approach that has been seen in many of the traditional high school textbooks. Now that we are in the business of space, it is easy but inadequate simply to add a chapter on space travel. We are seeing today the importance of radiation biology, but simply adding a chapter to the book is not enough. We are in a critical time in the teaching of science, and we must carefully look at what we are teaching and edit our course to its essentials.

All of the programs in science education must be involved in this process. If more science is being taught in the schools, then we can assume that the high school biology course can be built on a framework which it could never assume in past years. I see in the future very considerable and necessary attention given to the problem of the K to 12 sequence in which the biologist must take an active role. There must be considerably less overlap among all the grades so that biological concepts can be presented initially in the lower grades and then built upon during the terminal course at the high school level.

In conclusion, I pray that in biology we never encounter an experience similar to that of 1945, when atomic power was unleashed on a nation of scientific illiterates. The present and future biological revolution must not burst on a biologically uneducated country. We must encourage and demand the use of our splendid new resources in biology instruction. The revolutionary discoveries of biology today and tomorrow will affect us all. We cannot permit one student in our classes to learn of these discoveries, as Darwin put it, "as a savage looks at a steamboat."

Generalized Values of High School Chemistry

Z. V. Harvalik

Director, Basic Research Group
Fort Belvoir, Va.

IN ORDER TO appreciate recent advances in chemistry as potentially related to high school chemistry, one would have to discuss first why chemistry is taught in high schools in the first place: Do we want to train high school students to become chemists? Do we want to utilize the methods used in chemistry to achieve greater insight into its basic concepts? Do we want to train young people to use their powers of observation? Do we want to utilize chemistry as a vehicle for better understanding of our contemporary environment and civilization? One might also wonder if it is possible to use chemistry as a means of imparting objective methods which lead to increased insight into and understanding of our environment today, chemistry thus becoming a vehicle for transferring patterns applicable even to human affairs.

From the above very fragmentarily enumerated list of possible reasons for teaching chemistry, one would be inclined to believe that no one of these reasons alone should be utilized. Probably all of them will at times be of value. Therefore one should perhaps try to concentrate on those areas of educational values of chemistry which constitute a common denominator for the largest numbers of students attending chemistry classes.

Chemistry is an experimental science. It is a science that attains its information and insight from experiments postulated in hypotheses. Meaningful experimentation is possible only if one establishes quantitatively certain relationships through experiments which prove or disprove the validity of the hypotheses. This procedure, usually called the scientific method, is claimed not only by chemistry but by all of the sciences, but perhaps to the young mind, chemistry, more so than many of the other sciences, requires a considerable amount of knowledge and theoretical insight before such procedures become meaningful.

Another vehicle chemistry might offer to the young mind is observation in the course of experimentation. The power of observation, which should strive not to omit any phenomenon, can be trained; and chemistry does provide this training. This power of observation, when developed to a high level, could be transferred into other areas of human endeavor. It is important to note that such a transfer from one area of human endeavor to another, perhaps a very different one, is possible only when sufficient insight in the primary areas has been achieved. Whether this is possible on a high school level today is not certain by any means.

In a society as highly organized as the one in which we live today, one in which science and technology play a highly important role side by side with economics, human relationships, and statesmanship, to mention but a few, chemistry can give the young people some insight into the impact of a science on contemporary civilization. High school chemistry thus has a responsibility for transmitting such educational values as the processes of thinking, observing, and transferring—procedures used so effectively in the growth of this science.

Fifty or one hundred years ago, the chief values of chemistry were in the areas of observation of properties of elements and compounds and their chemical reactions. Innumerable data were thus collected. Later, with the advent of theoretical chemistry deriving its main strength from physics, especially in the areas of atomic and nuclear physics, these collected data could be woven into an interrelated logical fabric. Applications of chemistry to daily life, however, fostered a fragmentation of chemistry into such divisions as inorganic, organic, analytical, physical, and biochemistry. Dozens of new chemistries evolved, such as medicinal chemistry, metallurgy, ceramics, nutritional chemistry, chemistry of ferrous and nonferrous materials. Chemistry became a science loaded with specialists, and one can almost state today, as is the case with most of the sciences, that the chemist knows more and more about less and less.

Fortunately the progress made in theoretical chemistry, especially in the areas of nuclear, atomic, and molecular chemistry, revealed common denominators which helped to counteract the above-mentioned fragmentation. By pulling together the fragments into a meaningful whole where certain basic principles were understood, it was possible to make far-reaching predictions. This trend, which is perhaps now just in the beginning, will bear fruit in the future. Some of these unifying concepts are crystallized well enough to be included even in high school chemistry classes, concepts such as the atom and its nucleus, molecular forces, the chemical bond, stability of atoms and molecules, and the influence of environmental conditions on an element or compound. If these ideas could be injected into high school chemistry (using very selected examples so that they can be demonstrated in class, worked with in the laboratory, and their implications discussed in class as far as the young mind can bear), it would constitute a significant contribution to the high school curriculum.

When one scans the chemistry literature as well as literature in physics (and sometimes it is very difficult to distinguish between physics and chemistry), one notices that more and more quantification is being included. Physics and mathematics have thus become very important ancillary sciences. Research instruments as well as experimental equipment have become more elaborate and refined. Physical chemistry and physics are exerting more influence over all the other disciplines of chemistry. For instance, the classical chemical analysis through elimination is being replaced by special and specific reactions for elements, whole atomic groups, and compounds. Mass spectrometry, X-ray, neutron diffraction, nuclear magnetic resonance, and all the other techniques of high-priced instruments are utilized in obtaining new data, to say nothing of infrared, ultraviolet, and many other kinds of "spectroscopies." The properties of atoms, molecules, and radicals are described today in terms of electronic configurations, of excitability of orbitals, of resonance.

Environments are produced today in the laboratory simulating the cold of interstellar space, the heat of the sun, and the energy concentration of supernovae. Under these conditions there occur combinations of atoms about which chemists of yesteryear did not dare to dream. As solid state devices have revolutionized electronics, so surface chemistry today is applied to industrial production of chemical compounds and their purification. Ion exchange, zone refining, molecular centrifugation, adsorption are common words in the lingo of chemists and many laymen. Should all of these items be included in the high school chemistry curriculum? Or should a chemistry teacher transmit the basic concepts underlying chemistry (and physics as well) as he builds an edifice of chemistry that is tailored to a liberal education? This would not only make chemistry more meaningful to the students but would also make the world in which these students live much more understandable to them.

We are a long way from that goal. If one looks at the syllabuses, curriculums, and textbooks of high school chemistry, it seems that chemistry is 50 to 100 years behind the times. Oh, yes, you will find in a textbook something about the cyclotron, dacron, silicones, and hormones, and you will find a large number of exercises stressing quantitative relationships: how many tons of sulfuric acid will you get if you have 500 tons of zinc sulfide? Or how many milliliters of hydrogen do you get at 23.45° C. and 722.762 millimeters pressure when you electrolyze 27.889 grams of water? These are very nice exercises, but you don't have to perform them 5 days a week for 36 weeks with some very unmeaningful variations. High school chemistry is not made more palatable by changing the names of compounds and elements in such calculations, for if the principle is known and understood and the mathematical operation can be applied, a few examples are enough.

There are so many things in chemistry which are intriguing and interesting that it is easy to generate the enthusiasm of students and teachers, even though desirable experimental means are unavailable because of budgetary limitations. Nevertheless some obstacles must be overcome. It is not only the budget and the increasing indifference of young people toward learning in general, but also the attitudes of the teachers themselves, and one cannot blame them either. Nowadays they are called to teach chemistry, perhaps with very inadequate training in chemistry. Maybe their main subject was typing or driver education. Then there are chores that teachers, including chemistry teachers, have to do: supervising corridors to enforce no-smoking and other rules; supervising the loading of schoolbuses; filling out numerous forms for alleged statistics; correcting papers that are highly complex and long (and of their own doing). How they ever find time to teach chemistry in an inspiring fashion is difficult to understand. Still there are many chemistry teachers who do a wonderful job against all these odds. And even if they teach a high school chemistry course resembling a watered-down college chemistry course, they are yet able to fire the enthusiasm of many of their students. They inspire at least a few of them to have at home in the basement their little chemistry laboratories where they work on science projects, not necessarily for the higher glory of blue ribbons and other commiserations connected with science fairs, but for the pure love of gaining knowledge.

Our topic here is newer concepts in chemistry, and you may wonder whether we have really touched on that subject yet. But our goal deals with supervision for quality education in science. Quality education in science should not be concerned with encyclopedic knowledge of any of the sciences. Rather it should foster an understanding of the principles of a specific science that reach into all other sciences, so that a unified picture emerges. The methods, techniques, and reasoning used in the sciences should be acquired and applied to many areas of human endeavor. A high school chemistry course (including laboratory activities) and a chemistry or senior science club can accomplish these tasks. The incorporation of newer concepts into high school chemistry, concepts such as models of nuclear and atomic structure, of molecular configurations, of chemical bonding, would make the nature of chemical reactions and properties of compounds more meaningful. Electronic resonances and surface phenomena would aid in the appreciation of physical properties of elements and compounds. These discussions in physical chemistry would go, of course, beyond the gas laws, laws of multiple proportions, and the usually offered rudiments of chemical kinetics. Many phenomena should be not only discussed but also demonstrated in class and worked with in the laboratory, so that the observational power of the students is enhanced.

A chemistry teacher should not shy away from performing experiments during his lectures even if he has only limited facilities, equipment, and supplies on hand. He can pose a problem and let his students suggest how a certain principle or a certain reaction could be meaningfully demonstrated with limited means. This procedure would reach the mind of the student and train him to increase his power of logical and original thinking. For the student it would be original thinking, regardless of whether or not the suggested demonstration or experiment was originally invented decades ago by some Nobel Prize laureate. The pride evoked by such an achievement will bring striving for more accomplishments, for harder work.

In our age of science and technology, young people have been exposed to things scientific through television, magazines, newspapers, and movies. The attack on the last physical frontier, the conquest of space, fires their imaginations and increases their desires to know more about the sciences. Rocket fuels are not the only items in the realm of chemistry, yet members of junior rocket societies spend more time on chemistry used in rocketry than on chemistry needed in the classroom. Why? Because the environment of the rocket club is challenging, calculations are meaningful, and the senior members and advisers are competent scientists and engineers. They consider the junior members as their junior partners. They do not talk down to them. They pose problems to the students of the same degree of difficulty as they would assign to their own scientific staff. This attitude of the mature scientist (or engineer) toward the younger partner stimulates the student, causes him to work harder, and makes him proud of his achievement. In school the teacher talks down to his students; he adheres to the textbook rigidly; he does not react to searching questions from the class, perhaps because he cannot even understand the question, to say nothing of the answer. He wants to maintain the aura of a teacher who knows everything. He thinks he will lose the respect and admiration of his students if he admits he doesn't know the answer, and he doesn't realize that he is lost already. He starts to apply the techniques he learned at the teachers college or college of professional courses. He tries to produce a smokescreen around his subject matter ignorance. Sometimes he gets by with it, often not.

A teacher who knows his subject matter, who likes to be a teacher and enjoys sharing his interests with his students, will also strive to keep up to date. He will take subject matter courses at nearby universities, will participate in summer institutes, will utilize local scientific talents for consultation and lectures in his classes. His advancement may be handicapped, however, because he didn't take the required professional courses for certification renewal. But he will be an inspiring teacher rather than a sycophant. And if a teacher can say that he is able to teach chemistry, to touch the emotions of his students, he can really be proud of himself and of his students. Each of us at sometime or another has experienced the thrill of an experiment which brought to us the decisive experience of understanding.

To gain insight, to search for analogies and identities, to prove relationships and correlations quantitatively constitute the prerequisites of transfer. Chemistry, as any other science, can be the vehicle for such a process. A student equipped with the power of observation, of logical reasoning, gathering facts and learning to appreciate the meaning of these facts, will possess the tools not only for understanding our present civilization but for shaping his own future and the future of the world in which he lives.

Newer Resources for Improving Instruction in Chemistry

Robert L. Silber

Educational Secretary
American Chemical Society

OUR MISSION as educators is to strive for the greatest system of education, one that makes allowances for independent development, yet uses the simplest methods attainable. In the area of chemical education we can identify newer resources which may help us to attain these objectives.

I would certainly want to indicate very quickly that probably our newest resource is also our oldest resource. The well-trained teacher provides the best new resource that can be developed or devised for the preparation of youngsters. Today's teachers are being better prepared and are, in fact, much better informed in the sciences than they have ever been in the history of this country. This is largely due to the tremendous efforts of the National Science Foundation as well as other foundations in providing mechanisms for training through summer, inservice, and academic year institutes. Yet in our rapidly advancing technical world we also look toward new innovations which may assist the teacher.

The content of the course is also changing. It is here again that the National Science Foundation, as well as others, has made a major contribution by providing funds for the development of new course content materials. Two of these newly developed curriculums, namely, the Chemical Bond Approach (CBA Project) and the Chemical Education Materials Study (CHEM Study), are gaining wide acceptance in the schools. A description of each of these studies is given below.

Chemical Bond Approach

A conference at Reed College in Portland, Oreg., in June 1957, consisting of a group of high school and college teachers who had assembled to discuss the integration of high school and college courses, proved to be the beginning of the CBA Project. This conference was followed by another the following summer and the series of conferences have developed into the formally organized CBA Project.

In a recent description of the basic concept of CBA, the directors stated:

> If there is any one characteristic of the basis for CBA Chemistry, it is probably the belief that chemistry is inherently fascinating and that this fascination can be seen by students early in their exposure to the subject. To reveal the fascination, it is not enough, however, to have the student memorize the data of chemistry. Indeed, we would argue that chemistry is more than the facts which make up the information possessed by chemists. Rather, chemistry as practiced is a powerful process for uncovering and extending natural phenomena. The power resides in the combination of ideas and facts or of concepts and experiments. As the student finds himself able to participate in the process, he also finds fascination.[1]

The Chemical Bond Approach is based on the organization of chemistry instruction around a central theme. This theme has usually been stated simply as that of chemical bonds. An alternative statement would be that chemicals possess characteristic structures. Thus the course is organized to aid the student in his study of the interaction of conceptional schemes and observation. Successful laboratory work in the CBA program means that the student not only collects data in the laboratory but finds it meaningful and useful to him as he considers the implications of basic phenomena. The laboratory exercises are presented much like open-end experiments, since the student is presented with problems to be explored and, insofar as possible, he tries to decide what information is needed for solving the problem. In many cases the solution or some of the difficulties involved may suggest other paths of exploration. The student is encouraged to pursue such added excursions if they are intriguing to him.

The central theme of chemical bonds and the improved approach to laboratory work is supported by certain other central ideas which are woven into the course. One of these is the use of mental models. Chapter 1 of the course utilizes the first mental model by the representation of some unseen mechanisms in chemistry as those which might also be portrayed through the contents of a sealed box. The CBA directors recognize—

> that chemical reactions raise questions which cannot be answered solely by experiment and that, indeed, chemicals are to be regarded as black boxes whose interworkings are perceived through the eye of the mind. This general scientific strategy is taken up more directly as the student is led into the development of an atomic and molecular model out of assumptions and logic. Since the atomic model does not deal with all aspects of matter, a second model is added which deals with the kinetic molecular theory. In this latter discussion, a model is constructed which tends to become dis-

---

[1] *CBA Newsletter*, No. 9, February 1961.

> organized and thus to mimic the tendency of gases, liquids, and solids to expand. The two models, one for structure and the other for disorder, are then applied together for a systematic discussion of several reactions.[2]

Another interwoven idea consists of the use of electrostatics. The electrostatic theme is the basis for discussions where some assumptions about the nature of electrons are used to deduce the structure of some simple atoms and molecules. Still another thought that is developed in the course involves the presentation of free energy. According to CBA—

> A major assumption made about energy is that it is never created nor destroyed. This assumption is not the subject of experimental verification, although its consequences often are. In fact, one immediately useful consequence is the logical possibility of calculating the reaction energy for a reaction which does not lend itself to direct experimental determination. Free energy is introduced as a further use of the idea of energy.[3]

In summary then, we might conclude that the general theme of the CBA is one of chemical bonds. The course strongly projects the theory that, if a student has a real grasp of concepts, theories, and principles with appropriate facts to accompany these, a much better conception of the feeling of chemistry and what it can do is obtained as opposed to the learning of many isolated facts. In addition, the course develops ideas about mental models, electrostatics, and energy. Challenging experiments undergird the course presentation.

The course as developed by CBA is presently in its third year of revision. There are 82 teachers and 77 high schools involved in evaluating the course, with a total of 200 teachers presenting the course to 10,000 students. Educational Testing Service of Princeton, N.J., is assisting in the preparation of tests for the CBA Project. Students using the course are given achievement tests both at the beginning and at the end of the year so that their progress may be measured. The text will be published in final form by the McGraw-Hill Book Co. and will be available in the fall of 1963. Available with the text will be a laboratory manual and teacher's guide. The CBA Project is also interested in other areas related to the course. For example, they plan to determine the relationship between those students who have taken the PSSC physics course plus the CBA Course, as opposed to those who have not taken the PSSC Course but have taken CBA. CBA is also attempting to follow up on the CBA graduates and their success in college.

---

[2] *Ibid.*

[3] *Ibid.*

Chemical Education Materials Study

The CHEM Study Project is an outgrowth of a study committee set up in 1959 by the American Chemical Society to examine the purposes and content of high school chemistry courses with a view toward the production of a drastically improved course. Upon the recommendations of this committee, a proposal from the University of California at Berkeley to undertake such a study was submitted to the National Science Foundation. A steering committee of leading educators was assembled and on January 9, 1960, in Berkeley the group formally met and decided upon the general objectives of the study.

The general objectives of the study will be to develop new teaching materials for the high school chemistry course, including a textbook, laboratory experiments, films, and supplementary reading materials. The more specific objectives will be to diminish the current separation between scientists and teachers in the undertaking of science; to stimulate and prepare those high school students whose purpose it is to continue the study of chemistry in college as a profession; to encourage teachers to undertake further study of chemistry courses that are geared to keep pace with advancing scientific frontiers, and thereby improve their teaching methods; and to provide for those students who will not continue the study of chemistry in high school an understanding of the importance of science in current and future human activities.

It was decided in the very beginning to have a high school chemistry course strongly based in experiment and to have the text thoroughly dependent upon and integrated into the laboratory experiments, with the supplemental use of integrated films where they may be helpful. Another basic tenet was to make the course applicable to the general student who takes high school chemistry rather than to the gifted or upper part of the typical high school class. It was proposed that the talented student be helped through the preparation of supplemental material for use in the text, perhaps as fine print and, more particularly, through the production of a series of special monographs.[4]

Nine college and university professors and nine high school teachers assembled for a 6-week writing session during June and July of 1960. The course was drafted from this first attempt and was tried in 24 high schools during the academic year 1960–61. The course has since been revised two times and will be published in final form by the W. H. Freeman Co. of California in the fall of 1963.

The CHEM Study course is entitled *Chemistry, an Experimental Science.* As the title suggests, great emphasis is placed on the experimental nature of science. While the CBA course begins with an experiment utilizing a black box, the CHEM Study course stimulates the student by asking him to observe a burning candle. These written observations are submitted to the teacher who, on the following day, refers the students to the back of their texts where the observations of a burning candle made by a professional chemist have been recorded. In most cases, students can write approximately 6 to 12 observations, whereas the professional chemist, at least in this case, has made 53 observations of the burning candle. This immediately demonstrates to the student that his powers of observation can be improved. It also serves as a starting point for the introduction of phase changes—solids, liquids, gases, combustion, and chemical reaction. This course, like the CBA course, develops a scientific model for the atomic theory and demonstrates with these models, as well as laboratory experiments, how atoms are combined in substances. The course is closely coordinated with the laboratory manual which contains open-ended type experiments. As the course progresses, students are supplied with fewer directions concerning experimental procedure. The laboratory section is designed specifically to illustrate or demonstrate actual chemical theories or principles. The latter parts of the course utilize many of the concepts and principles learned in earlier chapters. Four chapters involve work with the periodic table and offer the student an opportunity to note the periodicity of elements in the rows and columns of the table. The last chapter of the text deals with various aspects of biochemistry.

---

[4] *CHEM Newsletter,* Vol. 1, No. 1, November 1960.

In both the CBA Project and the CHEM Study, students record their laboratory observations in a blank laboratory notebook. Carbon paper inserted between the sheets allows the student to retain a copy of his notes while submitting the original copy to the teacher. This system prevents the structuring of specific fill-in-the-blank-type questions and avoids regimenting the thinking of the student.

The CHEM Study course also is developing a series of 16-millimeter color movie films which are designed to facilitate further the learning of principles and concepts of chemistry. These films are concerned with subjects that are not easily demonstrated in the laboratory or classroom and which can best be illustrated by film. At the present time, 8 films are available in this series, with a total of 30 being planned. These films are available at a reasonable cost and can be obtained singly or in series from the CHEM Study.

The CHEM Study is also planning to develop a series of monographs on specific subjects. It is envisioned that one monograph might be prepared for each chapter of the text. The monographs would be designed for those students who have a great interest in a particular subject area or for those who are superior and seek additional information in some depth.

One of the most helpful aids being developed by this study is a teacher's guide. Each chapter corresponds with a chapter in the text and includes a development of the intent and approach of the chapter; an outline of the related ideas in the text; a list of items concerning the nature of new concepts in the chapter; a time schedule of assignments identifying the difficult and simpler problems; a list of typical questions that may be asked, together with suggestions for answering these questions; lists of supplementary materials, such as pertinent films, monographs, articles, and books, both for student reading and teacher reference; a background discussion on chemical principles and scientific philosophy; and answers to exercises and problems given in the textbook.

The teacher's guide is indeed a valuable instrument and can be utilized not only by the experienced CHEM Study teacher but also by those who are planning to initiate the CHEM Study course in their classroom. It also provides a potential answer to the often-asked questions, "How can we afford to retrain or update all the science teachers in the country?" and "Can a chemistry teacher who has not attended a CHEM Study institute be expected to teach such a course?"

In addition to the text, laboratory guide, films, monographs, and teacher's guide, the CHEM Study has also initiated the preparation of new wall charts, charts of names and formulas of common ions, an oxidation-reduction series, the relative strength of acids and bases, and an atomic orbital chart. These are commercially prepared and are available from commercial sources.

A very helpful mechanism developed by the CHEM Study group is the establishment of nine regional centers. Each week the teachers in a particular region who are using CHEM materials report to a regional center for several hours to ask questions concerning specific areas and to report on the teaching of various phases. This has not only been helpful to the teachers but also allows the project directors to obtain feedback on the teachability of each section.

Encyclopaedia Britannica's Film Series

This series is a complete film course in introductory chemistry taught by Dr. John F. Baxter of the University of Florida. One hundred and sixty lectures and laboratory demonstrations, including supplementary films, make up the course. The films are planned to fit the daily class schedule and to qualify students for full academic credit. Each lesson runs about a half hour. The film course has been developed to provide a background for further study of science in addition to serving those who do not plan technical careers. These films are available from Encyclopaedia Britannica Films, Wilmette, Ill., either as a complete set or in special lesson series. Student's and teacher's manuals accompany the course.

We have now discussed two major course revisions and a film series which together represent three of the major endeavors in developing a new curriculum in the field of high school chemistry. There are undoubtedly many revisions at the local level that are quite adequate and perhaps superior in many respects. It is hoped that some of the ideas from these three courses will find their way into new textbooks and will be utilized by teachers and supervisors at local and State levels.

Additional Aids for the Teacher

One of the best sources of information in all phases of chemical education is the *Journal of Chemical Education.* This publication reports on those research frontiers in chemistry which are of direct interest to chemical educators. In fact, this journal has often been called the "living textbook of chemistry." Regular reading here enables the teacher to keep abreast of events in the field of chemistry so that he may add new ideas directly to his course as it is being taught.

The lag or "trickle down" of current information, caused by publishing delays, is thus alleviated. Special features of the journal include "Tested Demonstrations" which teachers can utilize in presenting various principles and concepts. The chemical instrumentation section explains in detail the inner workings of new chemical instruments. A section on "Research Ideas for Young Scientists" describes, in an introductory way, projects that can be done by students. The ideas serve only as stimulators of further investigation in certain areas. One section of the journal introduces a system of demonstrations for the classroom which utilizes an overhead projector. A subscription to the journal should be a must for every chemistry teacher as well as every school library.

Films which no longer carry a product message but which are indeed concerned with the education of students are being produced in increasing numbers. The superiority of films produced by the various curriculum studies is indicative of new trends in this medium.

The advent of the paperback book is a breakthrough in the presentation of vast quantities of materials at low cost. A number of monograph series are available to assist both student and teacher in pursuing areas of chemistry to greater depths. Current series of monographs include the Physical Science Study Committee series, the National Science Teachers Association's *Vistas of Science*, the Prentice-Hall Chemistry Series, the Reinhold Publishing Corp.

Monograph in Chemistry series, and the Monographs of the Royal Institute of Chemistry. These are rich additions to the school library and can be obtained in quantity for sale by the school bookstore.

The commercial production of science kits has provided for the construction and use of scientific tools heretofore unavailable to students.

Programed instruction portends to make available still another device which may prove to be a major contributor to the process of learning. Various commercial companies are working on programed courses in the sciences, including chemistry. Programed instruction is available in many forms, but is still in need of further experimentation to find its proper place in the curriculum. Both CBA and CHEM are investigating the possibility of programing parts of their courses. In some cases it may be possible to program related areas, such as sections dealing with mathematics review, exponential numbers, or the metric system. A course that is being developed as an introductory course in chemistry at the college level will soon be available under the authorship of Dr. Jay Young, Chemistry Department, Kings College, Wilkes-Barre, Pa.

Other innovations, of course, include the increasing use of television in the classroom. The instruction of teachers and students by means of Continental Classroom is a prime example of this device.

The high school laboratory is also gaining attention. The use of newer chemical instruments in the modern high school laboratory is becoming a reality. A new book, being prepared by the Committee on Design, Construction and Equipment of Laboratories of the National Research Council, entitled *Laboratory Planning*, will soon be available from the Reinhold Publishing Corp. This book will contain a chapter on high school chemistry and should be of value to schools contemplating the construction or renovation of chemistry laboratories.

Safety in the laboratory is a subject of major importance. A new film entitled "Safety in the Chemical Laboratory" is now available from the Manufacturing Chemists' Association. Although primarily designed for use in colleges, many of the suggestions offered in the film are applicable to high school laboratories. A recent series of articles on safety in the chemical laboratory was published in the *Journal of Chemical Education*. Chemistry teachers in each State should request from the National Safety Council the bulletins on "Laboratory Glassware" and "Chemicals in the Laboratory." These two leaflets are very helpful in identifying two areas of laboratory work that cause frequent injury.

The American Chemical Society's national office in Washington, D.C., upon request, supplies various reprints of articles and other materials that are pertinent to the teaching of chemistry and chemical education.

An aid not to be overlooked is the use of atomic and molecular models. These are available from most scientific supply houses, with one of the most useful groups being made from styrofoam. The styrofoam materials can be cut to indicate bond angles, while the various sizes of spheres illustrate the relative sizes of molecules and atoms. These are particularly useful in demonstrating the spatial relationships of atoms and molecules. Available at relatively low cost, they can be obtained with the assistance of NDEA funds.

The Current Teacher

Teachers are indeed extremely busy people. The mechanics involved in the operation of the classroom, as well as the incidental duties indirectly applicable to the job, more than occupy a major portion of the teacher's time. Teachers must in some way try to remain current not only in their academic areas but also in the general field of education. At some time in the near future we must relieve teachers of all their extraneous duties and allow them full time to teach young people. The extraneous duties must be relegated to persons of lesser training. When this period is reached, the teacher will become more highly regarded as a responsible person in his academic area. In the meantime and until this glorious day dawns, I would like to suggest three journals to which the teacher, as a minimum effort, should subscribe and read regularly to ensure currency.

1. *The Journal of Chemical Education.* This journal, of course, has been discussed at some length earlier in this presentation, so no additional explanation need be offered now. The teacher who reads only one article a month can maintain some degree of contemporary thought in his academic area.
2. *Scientific American.* This magazine represents all areas of science and publishes articles in some detail by leading scientists from various disciplines. The articles are written in such a style that not only the well-trained teacher but many of the lay public can understand the significance and importance of them. A minimum of one article read per month will go far in preserving the currency of the teacher in various scientific areas.
3. *Saturday Review.* The *Saturday Review* has initiated a monthly education supplement sponsored by the Fund for the Advancement of Education, which prepares its contents in coperation with the regular staff. Articles are submitted by leading educators on all subjects of education from elementary school through postgraduate work. Various approaches to problems in education are presented in pertinent discussions. This is a very valuable tool in maintaining currency in the general field of education.

Introducing Newer Concepts of Physics

Herman R. Branson

Chairman, Department of Physics, Howard University

MODERN PHYSICS is an enormously complex field. According to a recent compilation by the American Institute of Physics, American universities list 213 distinct specialities for graduate study. Led by acoustics and proceeding through aeronomy, the list concludes with X-ray technology. Notwithstanding this diversity, physics attempts to describe the universe of phenomena in terms of a few concepts employed in hypotheses, principles, theories, and laws. Unfortunately, general statements, although they may engender a feeling of competence, really do little to aid the student in understanding the active problems being studied. We can state, for example, the conservation of energy (or of momentum or of spin) so that each of us will be able to repeat the law, and we can understand that such laws are observed in contemporary research in physics. But we would find ourselves ill prepared to read any of the articles in the current issue of *Physical Review* (probably the most distinguished journal reporting recent research in physics), where we encounter articles with such seemingly harmless titles as "Energy Losses and Collective Excitations in Crystals," articles which prove to be quite esoteric.

I believe, however, that a pedagogical device for acquainting the student or interested person with newer developments in physics is to analyze some simple early experiment and to show how the concepts, methods, techniques, and procedures have been developed or modified in contemporary applications. One of the experimental research areas of the Department of Physics at Howard University is mass spectroscopy: the finding out of just how much of certain isotopes are present in a given sample. In going back to the prototype apparatus of our equipment, we encounter a simple evacuated glass tube which leads unerringly to the major large installations of modern physics: the synchrocyclotrons, bevatrons, linear accelerators, and the like.

The Thomson Tube

This type of equipment (see figure) was first used by Sir J. J. Thomson while working in the famous Cavendish Laboratory at Cambridge University, England, some 60 years ago. Observe what happens when a high voltage is applied to the end electrode: the beam is bent on passing through a magnetic field. Observe, too, how it is attracted by a plate connected to the positive terminal of a voltage source. The end of the tube is covered with a fluorescent layer which detects the beam.

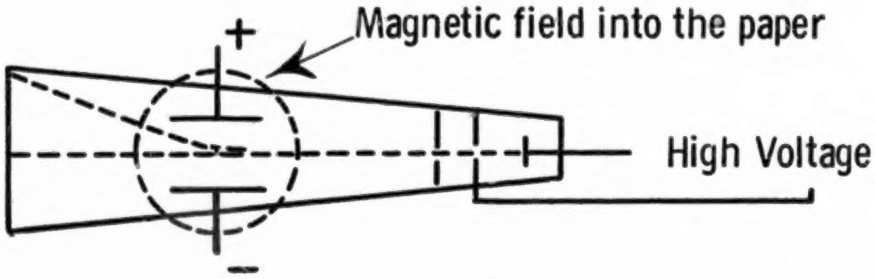

Diagram of speaker's demonstration with a Thomson tube

To fit these observations into a consistent pattern, Thomson employed certain concepts and principles. Since the beam did not behave as an ordinary light beam would, it seemed reasonable to assume that it was composed of charged particles. Our observations reveal that they are negatively charged. A more careful observation in a different tube would reveal that the curved path we see is really part of a circle. For circular motion we have some long-established, useful relations which we can invoke. One is the equality of forces wherein

$$\frac{Mv^2}{R}=Bqv$$

In this equation, M is the mass of each particle; v is its velocity; R is the radius of the path it follows; B is the magnetic field (called the magnetic induction); and q is the charge of the particle. Algebraic manipulation yields

$$R=\frac{Mv}{Bq}$$

as the radius of the curved path followed by the particles. Here this simple equation leads to our mass spectrometer or the cyclotron. For if we multiply by 2π and divide by the velocity, v, we have

$$\frac{2\pi R}{v}=\frac{2\pi M}{Bq}$$

The left-hand side is nothing more than the distance traveled in one revolution (the circumference) divided by the velocity. Distance divided by velocity equals time, and this time is that for one revolution of our charged particle of mass, M, and charge q. The important result is that this time, called the period, T, is then

$$T=\frac{2\pi M}{Bq}$$

so that for particles of the same charge and mass in a constant magnetic field, B, T is constant. This simple result makes the cyclotron possible.

The mass spectrometer employs the same basic equation in a slightly different fashion. Since we cannot easily determine the velocity, v, we make use of the fact that the velocity is imparted by our voltage source in the kinetic energy:

$$\frac{1}{2}Mv^2=qE$$

where E is in volts. Upon algebraic manipulation we obtain

$$\frac{M}{q}=\frac{B^2R^2}{2E}$$

Thus if we keep the magnetic field (B) and the voltage (E) constant, particles of the same charge but different mass will follow paths of different radii and may thus be separated.

Thomson eliminated the velocity by balancing the electric force against the magnetic, since E and B are easier to measure. He found that—

$$\frac{E}{B}=v$$

$$\frac{q}{M}=\frac{E}{B^2R}=1.76\times10^{11} \quad \text{Coulombs/kilogram}$$

Fundamental Techniques

Equally as important for the understanding of recent developments in physics is a summary of the techniques (and accompanying concepts) employed in looking at this simple experiment with the Thomson tube. We find that we need to (1) produce a vacuum; (2) produce charged particles; (3) generate, stabilize, and control a high voltage; (4) produce a magnetic field; and (5) detect particles.

One might use these five techniques as a guide to understanding contemporary research in molecular, atomic, and nuclear physics; they are employed, usually together but most certainly individually, in all recent work.

Extensions of the Basic Equations

The basic equations which we used might be grating on those of us who realize that the force exerted by the magnetic field is not along its direction. Continuing our analysis to where we get these forces aright leads to vector analysis and the Lorentz equation for the force,

$$\overline{F}=q\overline{E}+q\overline{v}\times\overline{B}$$

where all the quantities have both magnitude and direction save the charge, q, and the "$\overline{v}\times\overline{B}$," which is interpreted to yield the correct direction for the force, $\overline{F}$.

A most revealing extension of one of our basic equations is that for kinetic energy. If in one of our experiments, a descendant of the Thomson tube, we raise the voltage E to larger and larger values, we find that the speed of the particles does not continue to increase but levels off approaching a constant value, c, which proves to be the speed of light in empty space. The correct relation is found to be:

$$\text{Kinetic energy}=M_0c^2\left[\frac{1}{\sqrt{1-\frac{v^2}{c^2}}}-1\right]$$

with M_0 called the rest mass. This relation leads directly to the most famous equation of our time, the Einstein relation

$$\text{Rest energy}=M_0c^2$$

and states also the surprising result that the mass of a body is not constant but increases with speed:

$$M=\frac{M_0}{\sqrt{1-\frac{v^2}{c^2}}}$$

These three equations are the bases of modern nuclear physics. We see here how they fit naturally into a conceptual scheme (one devised to accommodate magnetic and electrical fields acting on moving charged particles) and in turn fit this scheme into a consistent and integrated panorama of the physical world.

By following the proliferation of the ideas introduced to describe the observations of a simple but important experiment, we can gain more than the illusion of understanding. We gain genuine knowledge, an agreeable situation which stems from this basic goal of physics: the representation of all physical phenomena in a consistent schema with a minimum of concepts, hypotheses, principles, and laws.

Newer Resources for Improving Instruction in Physics

Ralph W. Lefler

Visiting Staff Consultant
American Institute of Physics

IT HAS BEEN aptly said that an essential part of teaching is to prepare the learner to teach himself. I think that we are slowly but surely moving in this direction, and I sincerely hope that we will not allow slight changes in the direction of the wind to deflect us from this course.

A recent issue of *Education USA* (May 10, 1962) has prophesied that great changes in teaching method are near at hand, that instructional materials of all kinds will be better used, that emphasis will be on communication rather than on the gadget, that greater emphasis will be placed on independent study, and that superior teachers will receive greater recognition.

Harry C. Kelly of the National Science Foundation has suggested that science in the secondary schools should be an integrated kind of course with individual laboratory and discovery more pronounced than now. I am told that each 11th- and 12th-grade science student at the University of Illinois laboratory school has a small individual cubicle in the science suite. He undergoes some of the experiences of a scientist while he studies and learns.

I am indebted to a recent work [1] of Paul Brandwein for some of the ideas that I shall now present. In times recent enough to be within your memory, we believed that scientists had developed a successful method which we called the "scientific method" and which we thought could be itemized into seven steps that could be adapted to the solution of any problem. Technology, a product of science, was taught as science. Few understood that the scientist's major purpose was to understand nature, that the scientist is a seeker of ideas, that his is a world of the mind and the imagination.

Science was considered to be a body of verified and certain facts. The work of great scientists was reviewed superficially and their experiments repeated. Teaching in science was a matter of telling.

---

[1] Paul F. Brandwein. "The Revolution in Science Education: An Examination of the New Secondary Science Curriculums." *Teacher's Notebook in Science*, Spring 1962. New York: Harcourt, Brace and World School Department.

The lecture-demonstration was an effective means of transmitting facts. Complete courses in physics were offered by film or television. "The spirit and process of inquiry" were hardly to be found.

Science taught by "telling" rather than by "discovery," as problem doing rather than problem solving, could not produce scientific literacy because of the rapid growth in knowledge.

The creative individual could not survive in a fixed curriculum. He has always been driven to discovery, though he may upset the stable world by his discoveries.

The Physical Science Study Committee

The Physics Curriculum of the Physical Science Study Committee is an outgrowth of the rebellion of students and professors of physics to the stultifying effects of the process and content of physics instruction of the type described above.

You must be well acquainted with the complete PSSC package, yet many of the teachers in your areas of influence are simply teaching more of the same thing in the same old way, rather than accepting the challenge which has been thrown to them by the PSSC to develop a more effective program of instruction in physics. With the risk of dwelling too long on an area with which you are quite familiar, I shall emphasize what I consider to be the important aspects of the PSSC offering.

The "package" offers text, laboratory guide, a four-volume teachers' resource book and guide, apparatus, films, paperback physics monographs and tests, all prepared specifically for this course. I think that it can be said that not one item was used for the sake of expediency.

The laboratory provides direct experience with phenomena. Technological examples are sacrificed. Selected concepts are carefully interlinked and developed at the expense of the broader coverage of physics. The philosophy is to provide a carefully prepared explanation of selected material which is reinforced by films and laboratory. The PSSC curriculum is centered around the concept that matter and energy are conserved; that space, time, and matter cannot be separated. The relativistic view is presented, but Newtonian mechanics is not discarded. The sun's energy is found to come from a sustained fusion reaction; light emitted by the sun is both wave and corpuscle.

The laboratory guide suggests experiments using simple apparatus and is well coordinated with the text. Concepts are studied by way of the text, the laboratory, and the film.

Forty-four films have now been produced. These have several purposes: to help the teacher with new techniques, to present new phenomena that the student would not otherwise be able to observe, to supplement the text with added explanations of difficult concepts, and to show scientists at work. In my opinion, these far surpass most previous films in accomplishing the above purposes. Most of these films could be used to strengthen any good physics course.

The tests were developed by the Educational Testing Service. They emphasize the applications of principles rather than the recall of information.

About 24 monographs in the Basic Study Series have been produced to date. These are not intended as required but rather as free reading to provide added understanding of basic concepts.

The PSSC course is a demanding one. It is not now clear whether students who are not highly motivated will stay with it. It has brought about the strengthening of texts and curriculums which have been developed since its content became known. Some material previously taught in high school physics has been moved to earlier courses. Far less attention is given to technological applications (sometimes to the concern of those who feel that students are thus guided away from the field of engineering). More serious attention is given to basic physics concepts; more emphasis is placed on laboratory instruction. Some material previously found only in college level courses is being introduced at the high school level. In general, more is expected of the high school student of physics. There are many evidences that this trend is mostly good.

Professional Societies and Their Publications

I should now like to review the work of professional groups with a basic concern for physics education and to tell you of some of the newer resources which can aid both teachers and students to accept the greater demands that are being placed upon them.

Let us now look at the societies most concerned with the teaching of physics, the American Association of Physics Teachers and the American Institute of Physics. The American Institute of Physics is a corporation having as members the five principal scientific societies in the field of physics in the United States. Its purpose is the advancement and diffusion of knowledge of the science of physics and its application to human welfare. To this end it publishes journals devoted mainly to physics and related sciences; makes reliable communications as to physics and its progress available to channels of public information; carries on a comprehensive program aimed at strengthening physics education at all levels; cooperates with all organizations devoted to physics; promotes unity and effectiveness of effort among all who are devoting themselves to physics by research, by application of its principles, by teaching or by study; and fosters the relations of the science of physics to other sciences and to the arts and industries.

The American Association of Physics Teachers is the society of most interest to teachers. It is devoted to the teaching of physics and to the furtherance of appreciation of the role of physics in our culture. High school teachers make up 10 percent of its current membership.

The AAPT educational program includes a wide range of special projects and activities planned to advance the teaching of physics.

Two national meetings are held annually. The summer meeting is always held on a college campus. The winter meeting is held in New York City. The meeting scheduled for January 1963 will carry one full day of program planned to be of special interest to secondary school teachers of physics. This will be a departure from past practice, since it will involve the scheduling of papers which would be of interest to high school as well as college people within a block of time when it can be expected that high school teachers can attend. In the past these papers were to be found interspersed throughout the entire period of the meeting. It is hoped that this plan will attract added papers of special interest to high school as well as college teachers. This greater concern for the teacher of physics at all levels is an outgrowth of an increasing desire to strengthen the lines of communication between physicists and physics teachers.

Twenty regional sections of the AAPT hold annual meetings on a campus in the region. Many of these meetings are planned to be of interest to all area physicists and physics teachers. Information regarding meetings and other activities of the AAPT can be obtained by writing the Education Department of the American Institute of Physics, 335 East 45th Street, New York 17, N.Y.

The *American Journal of Physics* is published monthly. The content is primarily geared to the needs of the college teachers of physics; however, with many advanced level physics courses now being offered in high schools, its content becomes increasingly important to secondary school physics teachers.

The AAPT is making a very serious effort to launch a new journal for high school teachers of physics. They hope to have the first issue off the press early in 1963; however, negotiations for the initial financial support of the effort are not completed so a postponement may be necessary.

The new journal would, when taken with the present journal, extend the coverage to include both precollege and postcollege instruction. The coverage of physics and pedagogy would be geared closely to the requirements of physics teachers in the high schools who work in one-man departments, where the opportunity to discuss advances in physics, ideas for course content, and problems in instruction are almost nonexistent. The journal will present topics in physics which will encourage the high school teacher to continue scholarly study of physics; it will also place emphasis on the problems of content, organization, and methods of teaching at the high school level.

While the new journal is intended for teachers of high school physics, this designation must be broadly construed. There are today sophisticated versions as well as several extensions of the 1-year high school physics course. The new journal is expected to contribute to all these endeavors. With this scope it will also be of value to those who are teaching certain first-year courses at the college levels, especially the teacher of terminal physics courses in the junior college.

Another purpose of the journal will be to improve communication between secondary school and college teachers of physics. Physics instruction as a whole will be improved when the teacher at one level knows what he can expect from his colleagues working at levels which precede or follow his work.

Momentum Books, a series of paperback monographs, are to be published for the Commission on College Physics and the American Association of Physics Teachers by the D. Van Nostrand Co. Their aim is to provide lucid, accurate expositions of important topics in physics, written at a level that is interesting and readily intelligible to students who have had no more than a good introductory course in college physics. Each title focuses attention upon a topic either not treated at all or not treated fully in introductory courses. These books should prove of interest to both high school teachers and the better high school students of physics. In effect they are second-level monographs, with the PSSC Monographs as the first-level series. The authors of these books will be professional physicists.

A reference source, "Demonstration Experiments in Physics," was prepared in 1938 under the sponsorship of the AAPT. Since that time the content of elementary physics courses at the high school and college levels has changed, and along with this many hundreds of demonstration experiments have been developed which reflect the tremendous growth and often dramatically emphasize the principles which underlie modern microscopic physics. In addition, new projection techniques have evolved. Many of these demonstration experiments, new visual aids, and improvements of old experiments have not been published. Those that have been are often not readily available in useful form.

The AAPT expects to have published by 1964 a new reference text which will bring together under one cover discussions of the best demonstration equipment and techniques developed during the past 20 years. The great variety and number as well as the increasing complexity and specialization of demonstrations makes it impossible for any one individual to collect, evaluate, and prepare a uniformly high quality text which adequately surveys the manifold areas of physics lecture demonstrations. This national collaborative effort by the AAPT is being coordinated at Rensselaer Polytechnic Institute by Profs. Harry F. Miners and Robert Resnick, project codirectors. They have an advisory committee of six physicists.

The new text is to be entitled "A Reference Source for Demonstration Experiments in Physics." The publication will be one or two 1,000-page volumes. Up to half of the demonstrations will have their nature, significance, and use described and will include complete shop drawings. The balance of the demonstrations will be described in such a manner as to permit the reader to duplicate the demonstration with a minimum of difficulty.

As in the case of the earlier demonstration book, a considerable portion of the content of this book will be directly useful to teachers of high school physics.

Demonstration Experiments in Physics, published in 1938 by McGraw-Hill and edited for the AAPT by Richard Sutton, is still a very valuable book of demonstration suggestions, and taken with the new manual referred to above will cover the spectrum of classical and modern physics.

In the spring of 1961 another team effort of the American Association of Physics Teachers and the American Institute of Physics, supported by a grant from Educational Facilities, Inc., resulted in the publication of a book, *Modern Physics Buildings: Design and Function*, by the Reinhold Publishing Corp. Chapter 12, "Laboratories and Classrooms for High School Physics," has been printed separately and is available from the American Institute of Physics.

The National Science Teachers Association will release the 1962 revision of their *School Facilities for Science Instruction*, published first in 1954. This is a book which should prove helpful to any teacher, administrator, or architect concerned with the building of a new facility or the remodeling of an old facility for physics.

The American Association for the Advancement of Science for many years circulated a traveling science library. As an outgrowth of this, Dr. Deason of the AAAS has published and distributed annotated bibliographies of science books for high school use. Each book listed in these bibliographies had to have the affirmative vote of a panel of scientists and science teachers. Recently the AAAS has published a bibliography of paperback books suitable for use in high school science instruction. This is available from the American Association for the Advancement of Science, 1515 Massachusetts Avenue NW., Washington 5, D.C.

Physics in Your High School is an American Institute of Physics publication for the improvement of physics courses. Among the subjects covered in this 136-page booklet are ways to help the physics teacher keep up to date, suggestions about course content, and lists of books and laboratory equipment.

Other booklets produced by the American Institute of Physics include:

Why Should You Study Physics in High School? published in 1959 to encourage 9th-graders and 10th-graders to plan for a course in physics.

Careers in High School Physics Teaching, published in May 1962, to encourage qualified young people to consider careers as high school physics teachers. The booklet contains brief reports by five practicing physics teachers about their experiences and satisfactions as teachers. After these personal statements the booklet takes up these topics: the demand for high school physics teachers, education for physics teaching, the duties of the physics teacher, teaching salaries, workloads, fringe benefits, and steps to take in obtaining a teaching position. The background information in this section is as specific as it is possible to make it so that prospective teachers will have a realistic basis upon which to make a decision about a teaching career in physics. College and high school teachers can play a key role in encouraging a greater number of their students to consider high school teaching careers.

Rewarding Careers for Women in Physics was published in February 1962. This booklet was written especially for young women who are considering careers in physics. It presents a realistic picture of both the opportunities that are offered to women and the problems that they face in becoming physicists. For a woman, as for a man, a career in physics can be rewarding and challenging.

The booklets mentioned above are available through the Education Department of the American Institute of Physics, 335 East 45th Street, New York 17, N.Y.

Films and Other Visual Aids

The AAPT Visual Aids Committee initiates and sponsors the development and improvement of various visual aids for the teaching of physics. It also evaluates existing aids as they become available. Working cooperatively, the AAPT Visual Aids Committee, the Commission on College Teaching established by the American Association of Physics Teachers, the Physical Science Study Committee, the Science Teaching Center of MIT, and Educational Services, Inc., are producing several types of teaching films. These are mostly intended for college and university use, but as in the case of the journal there is sufficient overlap to justify their being mentioned here.

Short single-concept films ranging in length from ½ to 3 minutes are being produced at Ohio State University by Dr. Franklin Miller under a grant from the National Science Foundation. Each film clip is designed to be used in a classroom situation of the teacher's own devising to illustrate some essential but difficult-to-demonstrate concept. The teacher will develop the subject in his own way, at a level suitable for his class, then use the film and go on with his lecture. Many teachers will prefer to use the film clips silently, supplying their own interpretation; a sound-track narration is added for those who desire to use it.

New films in the PSSC series which will be available during the coming year include *E.M.F.*, *Electrical Potential Energy*, and *Linear Momentum*.

Beginning with the October 1962 issue, the *American Journal of Physics* has been carrying a review of fairly modern physics films. In addition, there appears a critical bibliography of films produced in the 1950's and earlier. Ten university film libraries will stock these films to expedite their availability.

Issues of the *American Journal of Physics* for April 1961 and for May 1962 listed over 600 films useful in physics instruction. The films in this list vary in level from elementary to graduate school. The list is useful in locating titles. Other reference sources such as film library catalogs will be required to obtain a descriptive statement of content or a grade level suggestion.

Optical projection is becoming increasingly important as a means of making physics demonstrations visible to large classes. The classical approach to optical projection requires the use of a lecture room optical bench and a carbon-arc source. Within the last few years the use of the overhead projector with a 10- by 10-inch stage has grown in favor as a means of projecting slides, transparencies, and experimental arrangements. There are advantages to the use of a horizontal stage and overhead projection.

Prof. Walter Eppenstein of Rensselaer Polytechnic Institute has published a report entitled "The Overhead Projector in the Physics Lecture," summarizing the results of a project to develop new techniques, accessories, and experiments for the 10- by 10-inch overhead projector. The project was supported by a grant from the National Science Foundation. Among the topics discussed in the report are the production and use of transparencies, the overhead projector as a means of projecting demonstration apparatus, a breadboard for electrical connections in projecting circuits, and an X–Y plotter for the overhead projector. Some of the demonstrations described include a crystal model in which the "crystal" is built up by means of transparent overlays so that one atomic plane after the other is projected, animated slides showing such phenomena as a wave moving across a boundary, a $\frac{1}{r}$ scattering demonstration, a kinetic theory chamber, and a variety of projectible electrical circuits.

Regional Counselor Program

The AAPT and the AIP have jointly established the Regional Counselor Program in Physics as a means of aiding with the solution of local educational problems in physics. Professional societies in physics must obtain the active help and advice of physicists who are familiar with local educational problems if the full benefits of national efforts are to be realized. The improvement of physics teaching in the schools obviously requires local activity by physicists because precollege education is primarily a responsibility of the city, county, or State. Regional counselors have now been appointed in nearly every State. Their names can be obtained by writing the Regional Counsel Office at the American Institute of Physics.

The local situation will determine the specific program of activities to be followed by each counselor. A State might be carrying on curricular revision affecting school physics courses, and the regional counselor in that State would want to maintain liaison with the official curriculum committee and to arrange for the services of consultant physicists to the committee so that the physics curriculum would be appropriately strengthened. What is "appropriate," of course, will differ from one locality to another because of differing interests and differing resources of teaching competence, equipment, and space available to the schools. In another locality an industry-education committee might be at work to improve teaching conditions, and the regional counselor would direct the attention of the committee to some of the problems affecting the teaching of physics.

This program provides an added means by which communication between physics teachers, educational researchers, and research physicists can be improved.

Visiting Scientists Program

Nearly all State academies of science operate a Visiting Scientists program under a grant from the National Science Foundation. Visiting physicists are usually available under these programs.

The AAPT and AIP jointly sponsor a Visiting Scientists Program in Physics for High Schools. This is neither a visiting lecturer program nor an inspection program. Physicists are invited by the schools. They go as guests and colleagues. Although they may give lectures on some topic in physics, they will spend much time in informal conferences with students, staff, and administrators on problems ranging from the educational preparation of a physicist through course content and facilities to the discussion of a physics concept.

For further information and the name of the program chairman in your State, write the Visiting Scientists Program in Physics at the American Institute of Physics. Requests for visiting physicists should be sent to the State chairman.

High School Awards

During each of the last 4 years the AAPT High School Awards Committee has picked 10 high schools to be honored for their outstanding physics programs. At least one school is chosen from each of six regions into which the United States is divided. The other four are chosen without restriction, except that no two schools in the same size category are chosen from any region. The division of the country into regions and division of schools into size categories automatically eliminates the possibility of considering the schools chosen as the top 10 schools in the country. Dr. Stanley S. Ballard, chairman, Department of Physics, University of Florida, Gainesville, Fla., is chairman of the committee.

Future Curriculum Programs

At present there is a move to establish a team effort to produce a high school physics curriculum that stresses the historical development of the concepts of physics and relates physics discoveries to their cultural and social setting. This is no multimillion dollar program, but there is precedence for and support in the physics community for such an endeavor.

Added experimental curriculum developments to look for in the future are—

1. A physics course with some stress on the relation of physics to the growth of technology. This would take on the modern engineering point of view.
2. A physics-chemistry 2-year sequence. There is at least one good text now available in this area.

In general, the newer curriculums in physics will—

1. Put greater stress on pure science, although possibly not as much as in the PSSC course.
2. Place more emphasis on the laboratory as a place for problem solving and discovery, as a place where the student can begin to experience the thrill that comes to a physicist as a seeker of ideas.
3. Put greater demands on the teachers.
4. Put greater demands on the student to take personal responsibility for learning.

5. **Require a greater variety of teaching materials.**
6. **Be based on a continuing school-college cooperation, such as required for the development of present experimental curriculums in the sciences, but probably involving fewer people and with smaller budgets.**

Conclusion

Some work is being done in the area of preparing programed instruction materials in physics. Whether the programed text or a machine is used, we have in this a development which will aid the student to assume added responsibility for learning. He can learn certain parts of physics and test his own progress through self-study. Contact the Center for Programed Intruction, 365 West End Avenue, New York 24, N.Y., for further information. The center is a nonprofit corporation working in the area of translating research findings relative to learning and teaching processes into practical classroom application.

The PSSC is extending its initial course through an Advanced Topics Program. Chapter A-1, "Angular Momentum and Its Conservation," has been produced. Other chapters will deal with atomic structure and the special theory of relativity. A Preliminary Edition of the *Advanced Topics I Laboratory Guide* has also been produced. This presents suggestions for experimental studies of angular momentum, moment of inertia, angular acceleration, the Michelson interferometer, waves in a moving medium, and spectra. For further information, write Educational Services, Inc., 164 Main Street, Watertown, Mass.

I shoud like to close with a statement of the general conclusion of a recent American Association for the Advancement of Science-American Council of Learned Societies Conference which was "to be effective . . . a teacher must take his place in the community of scholars as well as in the profession of education." I trust that the materials referred to above may aid the teacher to meet this obligation.

III. Supervision for the Improvement of Science Instruction

Emerging Problems of Supervision in Science

John H. Woodburn

Instructor, Walter Johnson High School, Bethesda, Md.
Instructor, Johns Hopkins University, Baltimore, Md.

THESE ARE TIMES that call for superior leadership. The successes of our profession have been rather snowed under during recent years by the impact of a not very good press. The parents of our boys and girls have had many opportunities to read about the allegedly poorly trained, uninspiring, second-class scholars who have allowed science teaching to degenerate to a low level. About the effect of this I will have something to say later.

The training of teachers in general and of science teachers in particular has been subjected to such humiliating criticism that there are few science education professors who proudly claim to be yet in the business. What has happened to take from the science education scene the strong men who once so proudly claimed responsibility for leadership in the training of America's science teachers? True, there are yet a few names which come to our minds when this question is asked, but there should be many. Think of the vigorous growth that has taken place both in science and in education. Never before have so many young people been enrolled in so many science classes. Never before have millions of dollars been invested in proving and disproving hypotheses that hold promise of upgrading science teaching. Think for a minute about what is happening in connection with writing textbooks. This is now a multimillion dollar project staffed by large groups of highly talented men and women, while but a few years ago it was the activity of a dedicated man who could squeeze a few dollars from his wife's grocery budget and borrow time from an unknowing employer.

The time is ripe for the emergence of more and more great leaders in science education—leaders who can free their minds of patterns and habits inherited from days that are no more; leaders who can let their imaginations soar toward untried approaches to the teaching of science, yet still retain a clear perspective of who these young people are for whom our dreams are really intended; leaders who can structure their hopes and ambitions with enough commonsense to insure that there will develop in our science classrooms the improved teaching of which they dream.

For the first problem of supervision in science to which I direct your thinking, let me cite the attitudes which so many students bring into our classrooms. They come to be taught—not to learn. The success of the day's lesson is the teacher's responsibility, not theirs. Most students go along with the teacher willingly, but only after the teacher has earned respect. Students almost expect their teachers to be inferior, second-rate scholars, and they seem to be surprised when so many turn out to be well-read, knowledgeable people capable of downright dramatic presentations in their classrooms.

Why cannot our immensely powerful public information system develop among our young people a sense of education as opportunity—opportunity to be developed and exploited? Take from the shoulders of our teachers the burden created when our students think we are imposing upon them something the newspapers have painted with a rather sorry brush. Counteract the attitude that each day's lesson, each course is a thing in itself, something to be gotten out of the way. How can a teacher retain his enthusiasm for learning when he is constantly confronted with such questions as: Will this be on the examination? Do you take off for spelling? Do we receive part credit if we know the chemistry but make a mistake in arithmetic? Are you going to call for homework papers?

It has been my opportunity during the past few years to alternate between meeting classes in a public high school and in a university incidentally, in a very good public high school and a rather prestigious university. At each transition I can but marvel at the differences in the receptions given me upon meeting students in these two contrasting environments. In the university environment, everything favors a sense of scholarly and intellectual adequacy, competence, and fitness—a feeling that spurs me to present what the students seem to be anticipating. In sharp contrast, if left to their own devices, when I close that door to room 203 and confront my 35 well-fed, well-mannered, bright, enthusiastic young people, the general impression I receive is that for things intellectual they couldn't care less. But don't miss my point. If they see that I am intent on going ahead with the lesson, they settle down and quite often bring to bear on the lesson a degree of intellectual discipline and freshness that is just as stimulating as that which comes from students in the university environment.

But why must the public school teacher face this kind of reception? Why can't a civilization as dependent as is ours on vigorous education get it across to young people that school, especially their science courses, is opportunity—opportunity to make the most of? And that the teacher is only one facet of this opportunity, a facet either to be developed to its greatest potential or stultified until there results a simple lesson hearer, a taskmaster who lives from one paycheck to the next? At this point you probably wonder how idealistic can a man be. Idealistic I may be, but in my mind I am deathly realistic. I have seen too many young teachers who were deeply imbued with the spirit of intellectual pursuit who never adjusted to the shock of seeing their students spurn what they so sincerely embraced. They never survived the disenchantment of those first few weeks. Had they faced students conditioned to draw out what these bright young teachers had to offer, they would have been so firmly hooked by the satisfactions which come to the teacher that they would never have left the classroom.

Critical analyses are vital to the improvement of almost any system of thought or action. I accept wholeheartedly the proverb—criticism is the life of science. I cherish the all-too-rare student who is brave enough to criticize my teaching. But could it be that the intense waves of criticism that have been leveled against science teaching at below the collegiate level have not only reached the point of diminishing return but have also created in the minds of our boys and girls attitudes that may be the cause of that which so rightly deserves criticism? I refer particularly to the exile from the classroom of the intellectual environment and the kind of teachers who can stimulate intellectual pursuits. Make but a little progress in orienting the minds of young people toward thinking of their science classes as opportunity—toward thinking of their science teachers as resources to be cultivated, and you will achieve great progress toward improving science education.

Now let me put into the record two or three problems which can set limits on the effectiveness of the science teacher but which I feel to be beyond the domain of my special interests and training. I can offer no advice on the solutions to these problems, but I do want to admit that they can be vitally important. First, let me cite the obvious fact that the classroom and laboratory, their furnishings, equipment, and supplies become a factor that limits the work of the teacher. Unless the usual utilities are present and functioning, unless storage facilities permit easy issue and return of equipment, unless requisition procedures permit the teacher to obtain what he needs when he needs it, the hazard is great that the teacher will become the type of teacher who needs only textbooks and student desks

The problem of designing laboratories, storerooms, and preparation rooms that communities can afford and which contain no architectural faults seems to defy solution. Similarly, there seems to be no escape from the inconveniences, disappointments, and aggravations associated with archaic and extremely systemized procedures for obtaining routine supplies. But please don't shrug these things off as being typical of things science teachers are expected to gripe about. These problems *should* be solved. They *can* be solved, but it is not appropriate for me to spell out *how* they are to be solved.

A second set of factors which set limits to the effectiveness of a teacher and, thus, create another emerging problem of supervision in science radiate in a more or less subtle way from what I like to refer to as the front office—the administrative officials who are responsible for the overall operation of the school. If the administration can absorb all the pressures and interests which the typical American community likes to bring to bear on its public schools and still establish a general climate that recognizes and nourishes intellectual performance in the individual classrooms, then it becomes phenomenally easier for the teacher to produce this kind of performance. Fortunately, among all the problems of supervision, this problem seems to enjoy the greatest progress toward solution. Our Nation's high schools seem to be moving more and more toward emphasis on things academic and intellectually stimulating. It is true, of course, that all manner of nonintellectual announcements will continue to burst forth from the intercom even amidst the teachers' best prepared lessons. (One I heard recently that was good for a chuckle was: "The schedule of dog vaccination clinics is available in the main office.")

I touch on these problems only to record that they are important. They are beyond my domain and I have treated them quickly to save time for those problems which I do feel are those I have license to analyze and for which I have the courage to make some claim for the right to propose solutions.

I want to tell you about an approach to the teaching of science that is not at all of my own invention, neither is it a marked departure from the kind of teaching many teachers have always striven to achieve. Perhaps it is because only subtle differences distinguish it from our traditional concept of teaching that it seems to be quite difficult to communicate. In fact, I have been told that very few of the students who have enrolled in the science teaching methods course that I teach really grasp the spirit of what I profess until well after the course has been underway. And there are always a few who cling so tenaciously to their established concepts of what they think science teaching is, has been, and should be that they never seem to grasp or catch a glimpse of something slightly different. For these reasons, I am going to introduce my ideas through two quite different metaphors.

To meet the challenge of providing the kind of science teaching called for by the role of science and education in this second half of the 20th century, I hope someday to be able to teach science very much as my friends across the hall teach art. In the art department, each day's lesson is a small-scale excursion in the human endeavor of art. Each student is encouraged to start with whatever proficiency he may have in the pursuit of this endeavor and, hopefully, improve this proficiency in one way or another during the lesson. On occasion, the art teachers show their students some of the masterpieces executed by great artists or they may exhibit for analysis lesser works so that individual processes peculiar to the artist may be studied in detail. Quite often time is spent orienting the student to the cultural realm in which an artist lived and worked, so that the student might contrast his own environment with that in which great art seems to evolve. At times the students are encouraged to produce copy exercises, doing the same thing over and over until a degree of skill is achieved that enables the student to pursue his own artistic expression with excellence sufficient to merit his own appreciation. As I observe the students studying art (and sometimes I invent excuses to go into the art department simply to share their satisfactions) I feel that even the least gifted boy or girl is catching the spirit of art, that each is exercising his mind and hands in the things artists do, and that his accomplishments are directly comparable to the function of art in our society and civilization. Perhaps this personal reference opens for some of you a concept of the kind of science teaching I am trying to describe.

To capture even better what I want you to think about, imagine if you will that you are observing one of the teachers with whom you are associated. You would observe him with the perspective of the teaching I want you to think about if you were to keep in mind such questions as: Does this teacher really comprehend the spirit, structure, methods, and function of science? Is he developing with his students the characteristics which recur repeatedly in the personalities of practicing scientists? Is he exercising in his students the powers of mind that are essential to the pursuit of science? Does he use to motivate his students the things which motivate the scientist? Does his lesson plan parallel the approach scientists use to pursue their investigations? Is each lesson directly traceable to a puzzling event or circumstance that has captured the curiosity of mankind and demand either explanation or description? Are his students helped to elaborate hypotheses regarding the phenomenon up for investigation? Do his students take part in gathering data whereby these hypotheses are pruned and intellectually groomed toward maximum logical consistency? Do his students then bend their efforts toward designing experiments whereby these hypotheses can be tested? Does he encourage his students to examine the conclusions to be drawn from these experiments so that further and more efficient investigations may be planned? Finally, does he take time to examine with his students the impact of a newly formulated principle or an ingenious invention upon the beliefs and behavior of people in other human endeavors?

How can supervisors develop in teachers an appreciation of the true nature of the pursuit of science—its spirit, structure, and function? This is probably the greatest single problem a supervisor meets when he tries to advance his teachers toward this concept of teaching. Let us think toward that end for a few minutes. Science is a human endeavor. It is one of the things men and women do. Science is a dynamic, evolving accumulation of increasingly precise descriptions of nature's events and circumstances together with increasingly effective methods for achieving these descriptions.

I like to think of the pursuit of science as being like a mountain—one of the magnificent volcanic cones of western United States, if you will. Viewed from a distance, it is static, dead, its cold, rocky mass dominating the landscape. Not until one fights his weary way to the summit does he glimpse even a remnant of the fire and turmoil deep within its roots—the fire and turmoil which gave birth and substance to the mountain. It is for the teacher to help his students comprehend and become a part of a mountain, not magnificent Mount Hood, but a mountain equally foreboding, equally cold and lifeless when viewed from a distance, equally overpowering to the ill-equipped, the ill-prepared, the novice who has heard so many times the gruesome tales of other would-be climbers who abandoned their journeys without ever knowing the exhilaration that comes with the view from the summit—a view enhanced all the more by knowing that now he stands closest to the vital forces still smoldering within the heart of the mountain.

By no means is ours the first generation to seek ways and means to attack this mountain—to devote our three-score and ten to helping young people comprehend the spirit, structure, and function of science. Just as literature search precedes new explorations in science, the ethics of our profession discipline us to examine, albeit very briefly, the efforts of others to design science curriculums. We do this not to criticize nor ridicule, but because the chances are quite good that we can gain from what others have done, valuable assistance when we undertake our own journey.

Attempts to design science curriculums involve basic rationales which seem to fall into two categories. The framework for the curriculum exists either extrinsic or intrinsic to the pursuit of science. The first of these rationales, the extrinsic ones, attempt to erect some kind of scaffolding or other structure external to the mountain but from which a view of the mountain can be achieved, whereas the second rationale seeks a framework for building a science curriculum within the pursuit of science itself.

First, let us review several examples of the extrinsic type of curricular design. For No. 1, there are those curriculum designers who prefer to fashion the needs and interests of the state into a central but exterior structure and turn to the scientific endeavor for whatever segments hold promise of enhancing, protecting, or perpetuating the state. Students are sent repeatedly to the mountain and told to return with the wherewithal to build bigger rockets, design faster planes, lay out broader throughways, synthesize more powerful drugs, or fashion whatever is needed to increase the comfort, welfare, and power of a nation.

A second example of the curriculums that are designed around an extrinsic framework is found in those science courses that are based on the needs and interests of the individual. These needs and interests form the central structure of the curriculum, and the student is encouraged to visit the scientific endeavor whenever to do so holds promise of providing something to meet his needs or to satisfy his interests. There is the assumption that once his needs have been met and his interests satisfied, there will be sufficient altitude to the structure created therefrom to enable the student to view and appreciate not only the scientific enterprise but also all other human endeavors.

A third type of extrinsically oriented science curriculum establishes the student in a chair or at a classroom desk and equips the classroom with a wide variety of techniques whereby the scientific enterprise can be brought to him a bit at a time. Episodes in science may be captured on film and the film shown to the student or translated into the language of textbooks or monographs which the student is invited to read. There may also be a television screen in the room, a teaching machine, and many other devices whereby the day's segment of science can be effectively exhibited. Sometimes visitors who have explored or had a part in the creation of science are brought into the classroom to tell the student about that part of the mountain they have known. At other times the workers who are actually adding stature to the mountain come into the classroom, they may bring samples which they exhibit, and they may provide directions whereby the student can construct a model or replica of a bit of the mountain.

A fourth type of curriculum design can be compared to a ski lift, whereby an all-pervasive theme is used to acquaint the student with science and, ultimately, transport him to a vantage point from which to view the total endeavor. In the life sciences, evolution, in the physical sciences, the chemical bond or quantum mechanics, are examples of the kinds of concepts that seem to have sufficient substance from which to construct the metaphorical ski lift. Obviously the student must stay reasonably alert lest he be spilled from his chair, but it is the faculty or some other factor exterior to the student that is supposed to provide the energy needed to operate the mechanisms.

These four examples of curriculum design share the characteristic of building some kind of structure exterior to the actual pursuit of science and then using the structure to give the student a vantage point from which to comprehend and appreciate science. Let us now turn our thoughts to that type of science curriculum in which the central structure is intrinsic to the pursuit of science. Students are immediately involved with science. They are made to wrestle firsthand with the mountain, regardless of how massive or foreboding it may appear to be. In curriculums designed around structures intrinsic to science, each course leads or pushes the student toward his own pursuit of science. The methods of science dictate the design of the teacher's lectures, his use of teaching films, his lecture demonstrations, laboratory exercises, or whatever other pedagogical strategy he may employ. Class-motivating techniques are sought in the motives and drives that keep astronomers glued to their telescopes; geologists chipping away at the earth's rocks; psychologists trapped in their mazes; and physicists, biologists, in fact, all kinds of scientists locked in their laboratories.

I confess to being strongly prejudiced in favor of this type of science curriculum. Foremost among the several reasons why I suffer this prejudice is the brute fact of the enormous proliferation of science. The sheer bulk of the mountain renders completely impractical any type of curriculum that attempts to survey the whole of science. Teachers who would try to lead, coax, inspire, or drag their students up this mountain encounter frustrations bordering on the urge to abandon the whole business. Even if one chooses the easier going of spiraling around and around the mountain, it is a long, long journey, accompanied all the while by the threat of being buried by new avalanches of discoveries—discoveries erupting from the living core to come rushing down the slopes, obliterating the trail that the teacher may have followed during previous years or that was marked out when the teacher was enrolled in a summer course in plant physiology or atomic spectra.

Lash our teachers unmercifully, if you will, with orbiting sputniks or blast them with Polaris missiles, they can never master the whole of that enormous mass of knowledge that has been created by science. Enroll us in course after course, day after day, summer after summer, year after year, and even on our 70th birthday, I know we cannot face a class without seeming to be unprepared for many of the questions that are sure to be asked by one student or another, and rightfully so.

Nor can we rely on our textbooks to provide a stairway for students who are to comprehend science. Traditionally, textbooks represent the accumulated knowledge of science, the shell of our metaphorical mountain, its outer crust, the stuff that has been forced from the living core and allowed to spill down the slopes. Obviously, that which was first to be created now lies most deeply buried beneath the product of later eruptions. To harass further the would-be climber, the forces of time have reworked whole segments, so that only remnants remain of much of the original material. Even if this material were still available to textbook authors, very likely it would have to be sacrificed or condensed to barebone facts to make room for newer concepts. Most unfortunate of all, the young traveler is thoroughly insulated from the scene of action, from the human activity by which the mountain lives, grows, and has its being, when he is at the bottom of the mountain, when he is only beginning the study of science.

The time is ripe for science curriculums that bore bravely and abruptly straight to the living core of science. Attack the outer crust, the substance of the mountain solely for what it is. Use it. Appreciate it. Without it there would be no support, no base on which to rest the keystones that keep the whole enterprise from crushing down on us. But our goal is the living core of science. Let us be caught up in the excitement of provoked curiosity, the challenge of the yet to be known, the haunt of the unknowable. Let us risk the cruel whiplash of the misleading hypothesis and all the other tortures to be endured amidst the volcanic turmoil of our mountain's core. We know we can always find a haven of rest by following an easily carved stratum, using a specialty, as it were, to break through to the relative comfort of a snow-covered slope. But it is not for the teacher to set up camp and display proficiency in a specialty. It is for him to keep his students moving forever toward the heart of the mountain, to return to the turmoil of the living core where, if he be brave enough, he will try to thumb a ride on the powerful updraft created by the intense human activity that constitutes this core.

How can teachers be helped to construct and administer science curriculums that actually involve students in science, that actually launch students on their own pursuit of science? To me this question states what is, by far, the most important emerging problem of supervision in science. Help your teachers really comprehend the spirit, structure, and function of science. Back up the training they have in the facts, laws, and principles of science with reading in the history, philosophy, and logic of science. Encourage them to examine the original writings of the world's great scientists, living and dead, not only to see what these men have done but also to recognize the personal traits and characteristics that recur among practicing scientists. Insist that that the cultivation of these traits in their students is a vital part of the teacher's responsibility. Recommend that daily assignments place great emphasis on science as a human endeavor, as one of the things men and women do, as something more than adequate to capture the mind, heart, and soul of men and women. Put them in touch with good biographies of great scientists, and if there are good biographies yet to be composed, encourage your teachers to create them.

Elevate to a level of supreme importance the analysis of the powers of the mind that are exercised in the discovery of facts, laws, and principles. Let us stop taking refuge behind the apology that the methods of science are difficult to describe, that some vague principle of indeterminancy shields the scientist from either introspection or overt efforts to describe his approach and attack on a problem. It is true that we may never be able to state a formula whereby success in science can be punched into a computer, but we do know that there are some things which separate the men from the boys in the pursuit of science. We all know, for example, that the scientist must be able to exercise a ready and faithful memory, to detect resemblances and differences, to compare, to communicate, and to discipline his mind to stay with a problem long after fatigue has begun to gnaw at his faith that the problem will ever be solved. It is the failure to attempt to exercise the minds of our students that call for apology.

It may be naive to say that there is a pattern, a structure in the way scientists go about their work, that the stereotyped concept of a problem identified, hypothesis elaborated, experiment designed, conducted, and evaluated, is only a superficial description of the work of the scientist. But is there a more logical frame of reference to use in the analysis of episodes in science? Where can we turn for a better design for our lessons? I can assure you that no better lesson happens in my classroom than on those all-too-rare occasions when I can actually confront my students with a puzzling circumstance—puzzling because they see something happen contrary to what their prior experiences would have led them to expect—and then to help them observe the circumstances in which the event occurred, to search their brains for information previously acquired that would reveal a clue to the operation of some law or principle, that would, to quote Albert Einstein, "make the chaotic diversity of our sense experience correspond to a logically uniform system of thought." On those days when things really go well in my classroom or teaching laboratory, we find ourselves with several hypotheses, each equally logical, each holding promise of explaining our puzzling observation, and there is nothing for us to do but design and conduct experiments or investigations whereby we can obtain a basis for embracing one and rejecting the other of our hypotheses.

These are not the lessons that put students to sleep, that invite competing discussions of last night's ball games, that glaze the eyes of boys and girls fed up with the memorization of barebone facts they have been told they will need to pass college boards or to fit them for courses they have long since decided they want no part of. Nor are these the lessons that require a "hell's-a-poppin'" demonstration or animated cartoons to hold student attention.

Help your teachers dabble in the pursuit of science. Lead, coax, or inspire them to carry on their own small-scale investigations in science. Tell them the school's laboratories are their laboratories, that they are welcome to use the equipment and reagents, the reference books and supplies. Encourage them to requisition apparatus and supplies needed solely for their own research. Above all, take pride in what they do. Share their enthusiasm even when this enthusiasm stems from something other people have done or known for many generations.

Encourage your teachers to shepherd their students on small-scale excursions in the pursuit of science. If you feel that changes in education must come slowly, let them begin with the superior students for whom the usual class routine may be unnecessary. Build into your teachers' schedules each day a few minutes when they can help these students shape up individual problems, dream up reasonably unique hypotheses, and design and conduct experiments that hold at least some chance of yielding worthwhile data.

Use your resources to develop courses of study in which there is a maximum number of whole and entire episodes in science—episodes in which students can be confronted with all of the essential features of the pursuit of science. Make sure each episode begins with the events and circumstances whereby a phenomenon can be brought into the classroom in a manner that is consistent with the way it originally caught the imagination of scientists. Build into these episodes the "stuff" students need to create hypotheses, many hypotheses, and experiments, many experiments. Select from the well-stocked storehouse of science those episodes which reveal most effectively the characteristics of scientists, that portray the creation of their hypotheses, and illustrate the design of the experiments whereby these hypotheses are tested. Select episodes the analysis of which can reveal the powers of the mind that are exercised in the pursuit of science. Weave from selected episodes in science a course of study that will introduce the student to the things which motivate the scientist, that draw from him the intellectual performance whereby it is pursued, and give him the satisfactions which come from the discoveries and inventions that are its products. Let the processes of science be the target for your courses of study. To hit this target, you will, of course, need to include much of the produce of science, its facts, laws, and principles, but these will be primarily the wherewithal to launch your students into the pursuit of science.

The time is ripe for you to go all-out toward helping your teachers to teach as to be true to the spirit of science, consistent with its methods, and complementary to its function. Students will surely respond to the intense motivation inherent in the pursuit of science. They will enjoy exercising their minds. The experience they gain will insure that the scientific endeavor will continue to be staffed with young men and women who are more than capable to continue the advance of science and the improvement of our civilization. It is for you to give the leadership. This you can do. Things are building up on your side. Textbooks are becoming available that are literally millions of dollars better than those they are to replace. You have in nearly each of your systems, in fact, in nearly all of your faculties, one or more teachers in whom has been invested the assets of one or more summer or academic year institutes. Surely these and other gifted people who are staffing so many of the projects which are devoted to creating improvements in the teaching of science constitute the help you need.

You know the conditions which exist in our classrooms. You know where the bottlenecks are. You have been involved in the evolution of the psychology of learning. You understand who our students are. No one is in better position to pull together the assets that can be retrieved from the past and combine them with the resources that are presently available and give our teachers the leadership they need. I know no more promising star to which you can set your sights than helping your teachers to teach as to be true to the spirit of science, consistent with its methods, and complementary to its function.

Emerging Curriculum Studies in Elementary and Junior High School Science

Philip G. Johnson

Chairman, Science Education Division
Cornell University

AT NO TIME in the history of our Nation, perhaps in the history of the world, have such massive plans and developments been proposed and in some instances been underwritten for the strengthening of science instruction in elementary and junior high schools. In the last decade such plans and developments have produced a number of new curriculum materials and massive inservice programs for secondary school science teachers. These efforts and the continuing concern of scientists and educators about the strengthening of science instruction at all levels give us good reasons for believing that we are moving into a decade of developments and inservice programs for elementary and junior high school science teachers. It will be my intention to consider some of the more comprehensive plans and studies. These will undoubtedly play an important role in the emerging studies at State, city, and county levels. These comprehensive studies are also more familiar to me while most of the State and local efforts have not come to my attention.

The Beginning

When one is asked to discuss the emergence of anything, one is confronted with the question of where to begin. Much of what is emerging at the present time appears to have been in the egg or pupa stage for several centuries. As some of the present proposals and developments are being studied, one cannot help but remember such statements as the following:

> Since the beginning of knowledge must be with the senses, the beginning of teaching should be made by dealing with actual things. The object must be a real, useful thing, capable of making an impression upon the senses. To this end it must be brought into communication with them [the pupils],

> if visible, with the eyes; if audible, with the ears; if tangible, with the touch; if odorous, with the nose; if sapid, with the taste. First the presentation of the thing itself and the real intuition of it, then the real explanation for the further elucidation of it.[1]

The first beginnings of science at elementary and junior high school levels put much stress on direct firsthand observations. We might state that at its best it was the scientific study of the environment. In 1903, Liberty Hyde Bailey published his answer to the question, "Is nature-study on the wane?" He stated the answer as follows:

> Much that is called nature-study is only diluted and sugar coated science. This will pass. Some of it is mere sentimentalism. This also will pass. With the changes, the term nature-study may fall into disuse; but the name matters little so long as we hold to the essence.[2]

When we think about the essence, we can look back to the turn of the century for the emergence of science curriculums for the elementary and junior high schools. During those early years the most competent scientists of our Nation took a keen interest in these science efforts. They helped organize the courses, they wrote most of the associated books, they taught the related courses in the colleges, and they participated in institutes for the teachers. Much of what they helped to establish has through the efforts of less capable scientists become stultified, overorganized, verbose, exotic, dull, and of little meaning to the boys and girls who have studied the courses. The scientists of the Nation became too busy with developments in their disciplines and did not continue to exercise a paternal interest in the science studies for youth.

While much of the essence was disappearing from these early science studies, there were few cries of alarm. Only in the last decade or so have scientists taken a careful look at the precollege sciences, and they have been greatly disturbed by what they have found. They have found much information about science, some of it erroneous; they have found a great emphasis on technology and little emphasis on what they really consider to be science. They have found that experiments have become things to be done rather than an opportunity for discovery. They have found what is called the scientific method, but they do not recognize it as what they are doing as scientists. They are very unhappy with much that they find, and they have become eager to do something about it.

The Present

The nature of our present curriculum materials for elementary and junior high school science must be recognized when plans are being made to bring about an improvement. It seems important that we consider what teachers have been using when plans are being developed to bring out new materials. This is especially true when one considers the very large number of teachers and schools that make up the elementary and junior high school levels. The courses of study now available, many of which have been developed or revised in the last year or two, are basically unscientific in their essence and organization. The large number of textbooks, kept up to date by the authors and publishers, are developed to support or to replace the courses of study. These textbooks become more and more attractive through the use of color and artwork, yet often less desirable when compared to the essence of science. The authors of the courses of study and the writers and publishers of the textbooks have a strong following among administrators, supervisors, and teachers. Companies that produce equipment, films, charts, models, supplementary readers, and other instructional aids keep themselves informed about the suggestions in courses of study and textbooks. An important question is concerned with how much of all this that now supports elementary and junior high school science must be replaced, revised, or supplemented in the emerging programs. Can we, and should we even if we can, wipe the blackboard clean and start all over again?

---

[1] Johann Amos Comenius. *The Great Didactic.* Originally published in 1657.

[2] Liberty Hyde Bailey. *The Nature Study Idea.* New York: The Macmillan Co., 1903.

Let us take another backward look for a moment at the nature of the courses. About 15 years ago the Federal Department of State felt that the devastated countries of the world might be helped to rebuild their educational enterprise, their buildings, and their facilities if they could be informed about practices and materials used in the United States. A committee of the National Science Teachers Association had the opportunity to develop the report. The elementary science courses were described under 11 headings; the junior high school science courses were described under 22 headings. In the intervening years the topics have come to be known as units or problems, but much of what we have today is similar to such topics. The number of divisions for the various levels may have changed. Some new topics have appeared and some established topics have been left out. New information and recent applications have been included, but the idea of subject matter divisions for the courses appears to be well established as the basic plan of organization for elementary and junior high school science.

Dr. Albert Piltz, in a report[3] to the American Association for the Advancement of Science for their feasibility study, described the elementary science textbooks available in 1960 by comparing the treatment given to 15 topics. He gave 22 headings as the areas identified in the 10 series of textbooks that he studied. It seems correct to say that, for the most part, the elementary and junior high school sciences are currently organized and taught under subject matter divisions. The major emerging patterns seem to point to some distinctly new approaches to the organization of elementary and junior high school science courses.

---

[3] Albert Piltz. "Review of Science Textbooks Currently Being Used in Elementary Schools." *Science Education News*, December 1960.

Newer Programs

When one looks at some of the recent major plans for elementary and junior high school science, one finds in many cases that a clear frame of reference is lacking; in other cases the frame of reference is limited.

Science Manpower Project Studies

The 1961 report [4] of the Science Manpower Project recommends six major phases or areas to be developed in the elementary science plan. These are: (1) The Earth on Which We Live; (2) Healthful Living Through Science; (3) The Earth in Space; (4) Machines, Materials, and Energy; (5) The Physical Environment; and (6) The Biological Environment. Aspects of these six major phases are to be studied in each of the first six grades. Below a table showing the various broad areas to be studied in each grade, we find the following statement: "Obviously, there is nothing sacrosanct about this organization and grade placement, and a school system can modify this planned program to meet needs that may be unique in its community."

Each phase of an area is expanded in three ways: first there is a presentation of factual statements related to the phase, then a presentation of important generalizations, and lastly a listing of key questions. While experiments are suggested and laboratory work is encouraged, there are few experiments proposed. In a further illumination of the program, it is stated, "An elementary school science program should be judged not by its internal logic, but by how it works as teachers attempt to put it into action."

In a companion volume [5] of the Science Manpower Project, one can find a series of eight criteria for a good modern sequence in science at the junior high school level. Also given are certain factors which should be taken into account in designing an effective instructional program. At another place in the book one finds a listing of the topics to be included in science for the seventh, eighth, and ninth grades. There are 12 topics in this organization. They are for the most part not different from what one finds in textbooks and courses of study, although their order and emphasis differ somewhat from currently available courses. The suggestions related to the areas are organized under such divisions as general discussion, suggested understandings to be developed, topical outline, teacher bibliography. There are few suggestions about activities and only limited ideas proposed for experiments. The topical outline seems to be the most prominent part. It is my personal judgment that in these "modern" proposals there is to be found very little that is new and very little of the essence of science.

---

[4] Willard J. Jacobson and Harold E. Tannenbaum. *Modern Elementary School Science.* New York: Bureau of Publications, Teachers College, Columbia University, 1961.

[5] Abraham S. Fischler. *Modern Junior High School Science.* New York: Bureau of Publications, Teachers College, Columbia University, 1961.

University of California Project

A major Elementary School Science Project was organized at the University of California, Berkeley, in July 1959 with financial support from the National Science Foundation. Planning for this project began early in 1959 and involved a group of scientists and educators. The group through the project director[6] expressed their hope as follows:

> We hoped to reorganize the science program around those important and fundamental concepts, an understanding of which leads ultimately to an understanding of many diverse natural phenomena and to a feeling of familiarity with the natural environment.

They stated that it was their purpose to stress the concepts and methods of science, rather than the uses and usefulness of science. An additional item of concern to them was the failure of the existing elementary school science program to use and develop the pupil's skills in arithmetic. They reported that as a guide in their work there was not so much the desire to produce many successful units as the desire to learn—to explore what the teachers and their pupils could do or could not do. Each principal investigator chose the topic or area to be studied in the first year according to individual interests. There was, however, the general expectation that the topic would be appropriate for the elementary school and deal with a fundamental aspect of nature.

They reported 3 years later that the construction of a conceptual framework for the entire science curriculum, which was one of their objectives, had been postponed while they acquired experience to guide them in what could be accomplished in the classroom. Three units have been developed: "Coordinates," "Force," and "What Am I?" Experimental work has begun on two other units: "Atomic Structure of Matter" and "Animal Coloration and Natural Selection." In connection with teaching procedures they have stated, "It should be one goal of the science program to emphasize the source of the information, to bring this source as close to the children as possible, and to discuss the role of authority in science." They reported that they found it useful to consider two levels of mental activity: one observational, manipulative, descriptive, concerned with objects and skills; the other analytical, abstract, concerned with relations and understandings. They expressed their conclusions by stating:

---

[6] Robert Karplus. "Beginning a Study in Elementary School Science." *American Journal of Physics*, Vol. 30, No. 1, January 1962.

> We felt that the long-standing benefits of science education consist of an understanding of the fundamental generalizations of the various fields and of the practice of inductive and analytical thinking that construction or discovery of these generalizations entails. It is therefore the task of the teacher to introduce the materials in such a way that they will serve as a path to the ultimate conclusion rather than becoming and remaining ends in themselves. A fascinating question concerns the age at which and the way in which it might be possible to approach the children directly on the abstract level, rather than through the observational and manipulative as we have assumed necessary.

Dr. Karplus stated in February 1962 that, "The two ideas, scientific literacy and scientific inquiry, can be the basis of a science program." He expressed the judgment that in establishing scientific literacy, it is necessary to teach the significance of undefined scientific terms as a common vocabulary to all students. He expressed the belief that a meaningful definition of a term must be based on a set of operations and applications that use the term. He further expressed the belief that in ideal scientific inquiry new data are collected but are not interpreted immediately. In the process, inconsistencies between expectations and the new information are sensed. If no inconsistencies are sensed, then previous concepts will be confirmed and become stronger. If an inconsistency is sensed, there is much activity to verify this discovery and to revise previous concepts, if necessary.

As far as a science program over several years is concerned, Dr. Karplus states:

> It is possible, however, that the focus of the science education should change as the children become older. For instance, the work in the early grades might stress scientific literacy. When the children are somewhat more mature in the intermediate grades, there might be more stress on inquiry. In the junior high school, perhaps, the pupils' historical perspective may be adequate to permit a review of the way current unexplained causes actually were invented and replaced over primitive earlier ones. Such a curriculum would provide a sound foundation for the teaching of the separate scientific disciplines in the high school and later. It would also produce scientifically literate graduates who might choose to study science further.

In March 1962 in a paper *Discovery or Invention*, Dr. Karplus joined with Dr. J. Myron Atkin, professor of education, University of Illinois, Urbana, in stating:

> Yet the objective of the science program is to teach children to look at natural phenomena from the distinctive vantage point of modern science . . .

> Indeed, it does not even seem very important to teach the children to invent concepts, because they can and do invent concepts readily. The educational problem, rather, is to teach the children to carry out their creative thinking with some intellectual discipline. And the development and refinement of modern scientific concepts in the light of observations would seem to be an excellent procedure for intellectual discipline.

When we study the writings of Dr. Robert Karplus and his associates at the University of California, Berkeley, we find a great deal of uncertainty about the nature of the science program from the kindergarten through the junior high school. While it may begin with a considerable stress on scientific literacy and gradually change to greater stress on scientific inquiry and still later in the junior high school to more stress on the historical developments in explanations of causes, yet a clear program in science for the education of children is lacking. Their progress on this problem has been to postpone the construction of a conceptual framework while they gained experience as to what could be accomplished in the classroom.

The University of California Project has stressed what can be done to develop scientific inquiry among children both by the direct efforts of scientists and by classroom teachers who tried to follow the ideas and materials proposed by scientists. Here it would appear that an important new dimension to elementary school science work has been brought into focus. The importance of careful observation, invention of concepts, use of arithmetic in helping to record and relate observations, development of operational definitions, planning experiments, analysis of ideas and conceptualization are major contributions to the emerging elementary and junior high school science curriculum. Here, it seems to me, we can note the essence of real science.

University of Illinois Project

The Elementary-School Science Project at the University of Illinois at Urbana, has been under the codirection of Prof. J. Myron Atkin of the College of Education and Prof. Stanley P. Wyatt of the Department of Astronomy. This represents another major center for emerging science curriculums for the elementary and junior high school. Their first product[7] on *Charting the Universe* became available in August 1961. This was used in about 275 classrooms during the school year 1961–62. The preface to the booklet states that the astronomers and teachers who wrote the report felt that it was important to know how the astronomer knows what he knows. The booklet and the teacher should help students to work like astronomers work and to understand the reasons behind the statements that astronothers make about the planets and stars. The booklet proceeds by statement, illustration, and activity to help students to understand such facts and ideas as the shape and size of the earth, the distance to the moon, the size of the solar system, the sizes of the planets, the orbits of the planets, a scale model of the solar system, measurements beyond the solar system, and a view of the universe. This booklet and others in their series of three related to astronomy were developed during the summer of 1961.

---

[7] J. Myron Atkin, Stanley P. Wyatt, and staff. *Astronomy Charting the Universe* (Trial Edition). Urbana, Ill.: University of Illinois, August 1961.

As was the case with the project at the University of California, the Illinois Project does not present a plan for an elementary and junior high school science program. It presents instead a plan to explore what can be done with children in studying the area of astronomy and to do it in a manner similar to the way that astronomers have done it. Here is an area where it is rather difficult to plan and to carry forward numerous real experiments. The project does reveal how astronomers, as scientists, can combine their capabilities with those of teachers and educators in developing a series of trial editions for use in the schools. As such they have made a substantial contribution, and not only does it reveal a way of approaching the understanding of astronomical information but also it reveals a method by which the thinking of astronomers can help to make science instruction with children more like the thinking of astronomers. Here again we find, in my judgment, the essence of science.

Educational Services Incorporated Project

Another major center for emerging curriculum materials for elementary and junior high school science is Educational Services, Inc., of Watertown, Mass. A recent newsletter reported that a support grant from the National Science Foundation has made it possible to create this curriculum project, which has a steering committee of 11 persons. Their work on the present project was begun more than a year ago with funds from the Sloan Foundation and the Victoria Foundation.

The principal result of their earlier efforts was the creation of a preliminary fifth-grade embryology unit on the cellular nature of living things. This unit uses the subject matter of biology to acquaint students with some problems and methods of the sciences. The student uses his own laboratory equipment (microscope, soda-straw balance, self-prepared slides) and through questions the student is helped to reach conclusions based on his own observations. The student uses three kinds of measurements. He also uses quantitative representations as he graphs results of elementary chemical analysis of cells and the number of cells in a population as a function of time. The student is encouraged to design simple experiments. The student also observes actual living things, comes to conclusions, and then tests conclusions by experiments.

During the recent academic year, the project staff continued to experiment with ideas for additional units. A unit for first and second grades, in which students examine the behavior of fish by making observations and performing simple experiments, is being worked on, tried out, and revised. Other preliminary explorations are being carried out on the properties of liquids and gases, scaling and mapping, and animal and plant behavior.

An extensive plan for the summer of 1962 has been developed. The work will include the use of some units developed by them and some developed by other groups. A group of 45 full-time participants and 43 part-time participants are listed for the 1962 summer work group, together with at least 5 persons from Africa.

The only guidelines presented in advance to the participants are those growing out of the feasibility conferences developed by the American Association for the Advancement of Science with supporting funds from the National Science Foundation. The general statement is made that, after reviews of activities in relation to elementary school science and after some observations of demonstration teaching, it is expected that the participants, working alone or as teams, will decide upon what they would like to concentrate their efforts. They would then develop ideas, prepare materials and plans, try out these materials and plans with elementary school children, review their materials and thereby approach materials and plans for further reviews, revision, and expanded trials. There appears to be no basic design for a frame of reference.

Studies of the American Association for the Advancement of Science

The American Association for the Advancement of Science, a major center for developmental work, has shown much concern for science education at precollege levels. Scientists of the association have participated in the several curriculum studies for the improvement of science courses at senior high school levels. Their affiliate, the American Nature Study Society, with a representative on the council since 1926, demonstrates that the interest of the association in science for young people is of long standing. During 1960 plans were formulated for more active involvement in developing science studies for children at elementary and junior high school levels. There was one all-important problem in planning for such involvements: Were the school leaders, the supervisors, and the teachers ready and interested in vigorous efforts to improve science studies for the young people? In short, was it feasible to plan and carry forward major studies on behalf of science for elementary and junior high school levels? Plans were developed to have a series of papers prepared, to be followed by three regional conferences for a study of the feasibility of undertaking major elementary and junior high school science curriculum studies. The 1961 report [8] presented eight points upon which there was substantial agreement:

1. Science should be a basic part of general education for all students at elementary and junior high school levels.
2. Instruction at the elementary levels should deal in an organized way with science as a whole.
3. There must be a clear progression in the study of science from grade to grade.
4. There should be no single national curriculum in science.
5. Science teaching should stress the spirit of discovery characteristic of science itself.
6. New instructional materials must be prepared for inservice and preservice programs for science teachers.
7. The preparation of instructional materials will require the combined efforts of scientists, classroom teachers, and specialists in learning and teacher preparation.
8. There is great urgency to get started on the preparation of improved instructional materials for science.

The AAAS study of feasibility recommended that there must be a science program with a clear progression in the study of science from grade to grade. Concerning the nature of this program, one finds such statements as the following:

> . . . Science instruction should not be limited to one of the separate disciplines, such as biology, chemistry, or physics, but should develop specific awareness of natural phenomena, good habits of observation, understanding of classification, function, quantification, order, and other basic ideas used in science, drawing on all the sciences for examples.
>
> . . . Although flexibility and variety are desirable, it is essential to have a well-defined structure for science courses, so that the load of answering extraneous questions does not become impossible for the elementary teacher, and so that the order and connectivity of science can be properly presented.
>
> . . . The simplest step for the child is to discover phenomena and to observe relationships that are new to him; at a higher level he can learn to discover relationships by experimentation; and at a still higher level he should learn to discover by abstract reasoning.
>
> . . . The science curriculum will, of course, teach concepts, theories, principles, and content areas; but the real purposes behind their selection must be kept in mind, and while the student is learning content he should also be learning methods of observations, the role of measurement and the use of instruments to extend man's senses, how to interpret and be critical of data, and that as a quest for new knowledge, science is constantly changing.

The report suggests the steps or stages which should be recognized in the development of materials. These were (1) identification of major scientific concepts, principles, and content areas to be covered and the preparation of a sequential plan for their development; (2) collation of present research data related to elementary and junior high school science instruction and definition of problems that need careful study; (3) preparation of alternative blocks of material (texts, teachers manuals, tests, and so on) for the several grades or content areas; (4) classroom trial, feedback of criticisms and suggestions, and revision of the preliminary materials; and (5) preparation of sets of materials for general use.

---

[8] *Science Teaching in Elementary and Junior High Schools*—a study made by the American Association for the Advancement of Science with support from the National Science Foundation. *Science*, 133: 2019–2024, June 23, 1961.

The AAAS developed and submitted a proposal to the National Science Foundation for an opportunity to proceed with the work that seemed feasible. They have received funds for the establishment of a national commission to guide the development of plans and materials for elementary and junior high school science projects. They also received support for initiating attempts to carry through their recommendations and to begin the preparation of materials. Two study conferences of about 10 days each have been planned for the summer of 1962. Here they propose to review what has been done by other groups and to consider suggestions for what should be done. It would appear that attempts will be made to use concepts and principles as a basis for arranging a science curriculum. Just what this project will produce by way of an emerging curriculum is not clear, but it seems certain that a very substantial effort will be launched which will have its impact on the schools within a very few years. Again it seems to promise, in my personal judgment, that the essence of science will be prominent in what is produced.

In the Future

What are the changes that are likely to become more noticeable in the years ahead? In what directions are our science curricular changes heading? Let me put my vision of these changes (I will not call them trends) into a few bold statements.

Change from much subject matter to relatively less subject matter.— Some general science teachers attempt to cover as many as 20 or 24 topics in a year. Others settle for as few as eight or ten. The change from a 4-year senior high school with 1 year for general science to a 3-year junior high school followed by a 3-year senior high school has meant that general science could be scheduled for a 3-year interval. Some science teachers took the 24-or-so topics and spread them over the 3 years, arriving at about 8 topics per year. Since in many schools general science is taught for only a single term in the seventh and eighth grades, some assigned 12 of the topics to the seventh and eighth grades, leaving 12 for the ninth grade. Again some other schools adopted some type of a spiral plan in which topics studied in the seventh and eighth grades were studied again at a higher level, in the ninth grade or later. This meant that the number of topics could be reduced substantially from the number of 20 or 24. The high school physics course often having from 6 to 12 topics has been reduced to 4 topics. Some leaders propose that the elementary school teacher at a certain grade level should not be expected to teach a multitude of 6 to 20-or-so subject matter areas, but should be encouraged to prepare for effective work in but 1 or 2 areas. Just how his problem will be resolved is yet to be determined, because some leaders propose that an elementary or junior high school teacher should not teach topics at all.

Change from one problem-solving method to many relatively unstructured methods of inquiry.—Problem solving in science has, to many persons, been a clear set of steps leading from problem to evidence and then to conclusions. Some insisted on adding a phase called application. Some had very clear ideas about just how the gathering of evidence should be done. All in all it was a problem-solving method and many teachers went through the motions thinking that they were contributing to a pupil's understanding of the scientific process. Most of the persons who encouraged this view of problem solving had had little experience with scientific research and knew very little about how scientists went about finding and solving problems. In recent years some very competent scientists have given their time and talents to helping young people understand science and scientists. Teachers who study their efforts are a bit confused because they do not recognize what they had come to regard as problem solving. Furthermore, in studying how scientists find and solve problems it has become evident that they do not follow a series of steps that one can find in the work of different kinds of scientists. They do find problems in many ways. They do approach answers in many ways. It is coming to be recognized that the best way to help young people to understand the scientific process is to help them find problems and to seek answers rather than to tell them how scientists do it.

Change from use of a book in a series to the use of many books.—The great majority of science teachers, especially the teachers in junior high school and in elementary schools, have relatively little preparation in the sciences. They are often expected to teach science areas where they have had no college studies or even high school studies. Furthermore, they may be expected to teach several different subjects with a day full of school responsibilities. They have come to accept the adopted textbook as their guide to organization and content. Library facilities are often limited and there is little time or help to learn about the materials. The school librarians often do not know what books to buy, and they select books from some science list in order to have materials for the few students who ask about books in the area of science. Recently scientists have given their judgments concerning good science reference books for the precollege levels. Such books have been assembled in sets and circulated in schools; the results of their availability have been studied. Books on these progressively improved lists have been purchased by many schools, while other schools have made a beginning and plan to continue purchasing such reference books. With such reference materials available and an encouragement to stimulate wider reading both by school and by home influences, there is more and more use of reference books. With this growth many students find the reference books to be interesting and helpful in gathering information for topics and projects. In recent years the growth of science exhibits and fairs has caused students and teachers to look to reference books as aids, and they are beginning to use more and more books rather than depending on the one textbook. The influence of scientists who continually use many reference materials, both books and periodicals, has caused teachers to catch the idea that it is rewarding to the student as well as the teacher to use a number of books. This change is likely to continue.

Change from an emphasis on accumulating knowledge to an emphasis on how to find out and create knowledge.—One needs only to study the kinds of tests that teachers over the years have been using to note that there used to be an attempt to determine only the subject matter that pupils had learned. Pupils were expected to mark statements as true or false, to match a statement with a word, to select a proper completion, or to answer a question in some expected form. The answer was the important thing and the way the student progressed toward an answer was of no avail unless it led to the correct answer. The answer determined the grade, and an error in one operation was just too bad. Gradually there has come to be concern for the student who can carry through the question, but in so doing makes an error which results in an incorrect final answer. Partial credit for the correct method has become acceptable in many situations. More recently, tests have been constructed that are built on known information, or the needed information is made a part of the question, and the student is tested to note whether or not he can interpret or use the information properly. Tests of the ability to apply what has been learned to novel situations have followed, until now there are tests available that are considered to have little recall base and much need for thinking and reasoning. Recently tests on understanding science have become available in experimental form. We can expect to see more and better tests that measure the students' ability to think like scientists think.

Change from facts and factual concepts as instructional goal to skills in inquiry as the teaching goals.—Most courses of study in use today give the impression that concepts have been accepted as the teaching goal, but one need not look very far below the surface to note that information related to a topic is given even more stress than are concepts. In many cases even the concepts are statements of fact and little more. There is a clear topical organization in many instructional guides developed by committees of teachers. The guide for a particular grade is divided into a number of topics. Each topic in turn is outlined so as to show the subtopics. In a number of instances such an outline forms the major left-hand column of the guide. The second column may be devoted to the concepts to be achieved and, farther to the right, there are columns for activities and references.

There appears to be an increasing number of instructional guides that begin with approach activities which are designed to create questions or problems in the minds of the students. One such problem is made the subject for investigation. Students are encouraged to propose hypotheses and then to gather evidence to support or refute the hypotheses. Evidence is to be obtained from experiments, most of which are suggested, but there is more and more encouragement for students to design experiments that may produce significant evidence. Students are also encouraged to consult reference books and to interview people who are thought to know something about the problem under study. Later students are encouraged to select and to restate, with proper caution, what appears to be their best hypothesis and to use it in attempts to explain phenomena. Very recently expert scientists have taken an interest in developing guides for the study of their area of specialization with the spirit of inquiry uppermost in mind. Concepts still rank high as the objective to be sought, but they are not listed and therefore not likely to be taught as such. They are to come quite naturally from the process of inquiry. This change seems to be in its initial stage of development.

Change from teacher-selected concepts as instructional goals to concepts as they may arise in the process of confirming or rejecting hypotheses.—We must admit that most instructional guides and most textbooks indicate rather clearly the statement of the concepts that students should acquire. There is not much encouragement for allowing students to state their own hypotheses and, following a time devoted to seeking confirmation or rejection, to come to their own concepts. However, this seems to be the direction that some leaders are encouraging teachers to take. Stress on the processes of inquiry would seem to promise that there will be more and more encouragement for this type of teaching. It is one thing for an expert scientist to guide students in this process and quite another for a rather poorly prepared teacher to do so. Will it be possible to develop manuals for the great number of mediocre teachers who will need much guidance in order to feel any significant sense of security in this type of teaching? How can teachers be developed for the inquiry type of teaching? While the change seems to be pointing in the direction indicated, it is doubtful that we have enough evidence of this change to think of it as a present trend, but it seems to be indicative of a future trend.

Change from reliance on qualitative observations to more and more stress on securing and recording quantitative observations.—Many leaders in education have stressed the values to be derived from personal firsthand observations. Observations concerning shape, color, and texture, together with changes in such qualities, have been encouraged by teachers. Students have been asked to represent these and other qualities on paper, with clay, and in words. Scientists who are working at the forefront of scientific developments see in the precollege science studies a great and seemingly deliberate avoidance of the quantitative observations, which are the very heart of science as practiced by scientists. Their influence and the growth of movements to make mathematics more meaningful to the students have brought a resurgence of stress on quantitative measurements. Using conventional units, as well as creating units which are later related to conventional units, has come into rather common use. Along with this change has come the use of models, graphs, tables, and new symbols for presenting and representing what has been observed. These help students to sense relationships. Use of available measuring devices has been encouraged while scientists have put their minds and hands to work in search of inexpensive and simple ways to make relatively accurate measurements. The search for similarities and differences calls for accurate observations, and such observations require measurements to be noted and reported. We can expect this change to continue.

Change from science experiences as preparation for secondary school science to experiences for basic education of all students.—Developments in recent years and the massive attempts to develop a science program for elementary and junior high school students indicate that this change is being accelerated. Leaders for more than a century have been pointing out the values of actual studies of the environment. The object study methods gave this a strong impetus, and the change from mere object study to the scientific study of nature hastened the development of science studies for all youth. While the senior high school sciences in the early part of the century were for the relatively few students who continued in school beyond the early grades, the development of general science opened the area of science to a large number of youth. Few people question the need to develop a scientifically literate citizenry, and school leaders who have no organized science program are actively seeking ways to develop a program to help their teachers include science in the program of studies. The change is clearly a definite one, but how best to guide the change is still an area where there are many disagreements. The efforts of competent scientists working with other knowledgeable people in the spirit of mutual respect and good will are certain to arrive at several acceptable answers. As a result, this change will bring good science experiences for all youth. Many persons think this change will also result in the best science experiences for those who will continue in the study of science.

Change from science as something to be learned from books to science as something that grows out of a series of experiments.—Some active leaders, who provide college work for elementary school teachers in the area of science, are deploring the purchase of boxes or kits of science equipment, since these are placed in the schools without the teachers' knowing what to do with the materials. The boxes or kits usually contain some type of a guide giving the teacher instructions for performing a large number of experiments. Once a teacher develops confidence in using items to show an experiment and notes the delight of the pupils, there is a desire for ideas concerning additional experiments. Teachers who take courses to prepare them for better work in the area of science usually give high praise for their work on such experiments. Often such courses have a number of teachers who serve at different grade levels, and when they first try their experiments with their pupils they find high interest. If they try these same experiments a year later, they find a few students who remark that they saw or tried them last year. Each year, unless there is some plan for grade placing the experiments, the problem of duplication becomes greater and more annoying. While science experiments seem to be possible for teachers and of high interest to pupils, something other than experiments seems necessary to a science program in the schools. The change toward some grade placement of experiments within a larger framework promises to continue.

Change from a science program based on topics to a science program based on a more fundamental frame of reference.—Many of the outstanding scientists who have interested themselves in the science programs for elementary and junior high school have become unhappy with what they have found. They do not consider the covering of science topics and the doing of experiments as representative of what science really is. Some of them seem to feel that the covering of topics and the doing of demonstrations may be worse than not doing anything at all. They speak of discovering science concepts, helping youth to interpret natural phenomena, developing understanding of science, learning the ways of scientists, and becoming effective inquirers. Some of them have been giving much time and thought to developing materials and trying them out with children. While they often state that there must be a planned scope and sequence to the science work, they are not at all clear concerning the nature of this scope and sequence as it pertains to grades 1, 2, 3, and so forth. While they are amazed at the number of diverse topics that teachers often have been trying to include for their grade, they are not definite in suggesting the much more limited scope that they seem to favor. While they are disturbed by a program based on different topics, sometimes in a spiral plan, from grade to grade, they have no suggestions concerning the way a sequence should be planned. While they deplore teaching "topics," in their own courses where most of our teachers receive their education they themselves teach topic after topic. The massive efforts being planned for the study of ways to formulate strong science programs for the elementary and junior high schools will give rise to different frames of reference that will present improved views of the scope and sequence of science for the grades prior to the senior high school.

Change from emphasis on technology to emphasis on science.—One of the aspects of our current elementary and junior high school science courses which has bothered scientists has been the great attention to uses of science, including technology. In the new senior high school science courses there has been a deliberate attempt to omit technology and to stress science. Some leaders in science education have expressed their judgment that the study of high school physics as science, with little or no attention to technology, fails to challenge the capable science-interested student whose orientation is in the direction of the applications of science to problems of engineering and industrial production. They feel that some inclusion of technology would challenge and hold the interests of these students and would help direct a larger number of capable students into the study of engineering. Furthermore, they feel that technology is a part of our way of life, and to reduce attention to this area of applications is to fail to inform youth of an important area of everyday living.

The courses in general science have given much, many would say far too much, attention to technology in the various topics or units. Often the topic or unit would center around a product which resulted from utilizing the principles of science in meeting a human need. Perhaps it was the study of a home refrigerator or the automobile or musical instruments. The principles of science were given little attention, while the construction and operation of the device was given much stress. Applications or uses were often the focus of attention in many of the general science courses. The seeking of fundamental principles of science and coming to understand them through demonstration experiments and individual experiments were set aside in favor of reading the book about various technological developments. Many leaders would agree that general science courses have given too much stress to technology. Just how these courses can be made to reveal science and scientists in proper balance to engineers and technology remains to be developed. Just what attention can and should be given to the role of technicians and the developments in which they participate also remains to be clarified. The major studies currently in the formative stage promise to give searching attention to such problems.

Change from science that must be developed from a limited understanding of mathematics to science that is built on mathematics.—Some teachers of mathematics have in their own preparation given much attention to the sciences, especially the physical sciences. Undoubtedly many of them make use of real problems that must be solved in the sciences when they consider the related concepts and operations in mathematics. However, a very large number of teachers of mathematics have avoided the sciences in favor of more and more mathematics. For them the important outcome in the study of mathematics is to become prepared to understand further mathematics and to think creatively in mathematical terms. If we may judge from similar teachers in the colleges, we can note a very real resistance to the inclusion of problems from the sciences and engineering when related mathematical concepts are considered. There is even greater resistance to the inclusion of problems related to economics and finance.

Is any progress being made in relating mathematics and science? Dr. Irving Adler, who spoke to the State Supervisors of Mathematics at an Office of Education conference last year, stated that "the greatest mathematicians have always combined dedication to pure mathematics with a strong interest in its applications." In another statement, he remarked, "Now, more than ever, it is true that mathematics is the handmaiden of the sciences."

Are mathematics and science moving ahead hand in hand? While we see the inclusion of a type of laboratory work in mathematics classes and the use of mathematics in science classes, these seem to be the results of individual or departmental interests rather than the product of much interdepartmental planning. When one talks with science teachers and hears their remarks about the inability of students to handle the needed mathematical operations, one finds more evidence for a rather cool handmaiden relationship. Just how closely should mathematics and science be related? How can mathematics be truly a handmaiden to science and still be good mathematics? How can science teachers and science supervisors develop good working relationships with mathematics teachers and mathematics supervisors with the goal of improving both science and the mathematics instruction? Many leaders sense a growing kinship between those who serve in science and those who serve in mathematics. They sense that persons in each discipline have the important responsibility to advance the frontiers of their field. They also sense that advancement in one discipline conditions to a large extent the possible advances in the other. They believe that working relationships would be developed and extended, not only between these two disciplines, but also with leaders in the liberal and fine arts. Some would also include leaders in the vocational areas to the end that future citizens may be sensitive to and informed about the wide spectrum of human endeavors. Perhaps the change is becoming less and less invisible if it is not more and more visible.

Summary

What can one say about emerging curriculum studies in elementary and junior high school science? In brief, we can state that they began to emerge a century or more ago. There has been progress and regression led by energetic and dedicated leaders. One is impressed again and again with the tremendous change which grew out of the efforts of a single dedicated leader who felt that he had a great idea which had to be recognized in the education of youth. One can also note how leaders, at a particular time, built upon the ideas and developments of others. One can sense that individual leadership, while still strong, has been clarified and refined through working with other leaders in the preparation of reports and recommendations. It is possible to note a growing sense of responsibility in school systems for the careful design of curriculums and for the development of instructional guides to implement these curriculums. Only recently have school leaders been made aware of the great concern of national leaders in the sciences for the science instruction at precollege levels. This concern has now been extended to the elementary school and junior high levels. Here we have the concern not only of great scientists but also of outstanding school administrators, supervisors, teachers, and parents. The substantial plans that have been initiated, the additional careful plans that are now in the formative stages, the embryo plans that are merely alive—all promise what may well be a brilliant metamorphosis in the development of science programs for youth.

New Programs in Science Youth Activities

A. Neal Shedd

Specialist for Science Youth Activities, U.S. Office of Education

AT ALL TIMES and at all places, teachers have been much concerned with "what knowledge is of most worth." In the United States during the past 50 years the curriculum has been influenced by time and place. This period is studied by school administrators and curriculum directors caught up in the present period of rapid change. The importance of this broad view is necessary to avoid the pitfalls of opportunistic revisions sometimes characteristic of single school divisions.

Early in the century in many schools such extracurricular activities as orchestra and athletics were forbidden or discouraged. Later they came to be tolerated and finally welcomed as respectable and component parts of the curriculum.

During the 1920's it became apparent to many that education for leisure-time activities was worth while. Education for citizenship and for practical programs that would help to retain youth in school were recognized as a great need in the 1930's.

The school administrator has always been beset by the problems inherent in revising the curriculum, but the past 15 years has brought to the forefront another new challenge.

Today's emphasis on science activities in our schools has not been placed there by the educator. Some factors which have brought about the new emphasis are: (1) the scientific manpower needs of the Nation; (2) an unprecedented expansion of the scientific and technological enterprise; and (3) the need for a scientifically literate citizenry.

Since World War II it has become increasingly apparent that the national output of new scientists, engineers, and science educators has been inadequate to meet the needs of our Nation. This great lack of manpower is continuously accelerated by economic progress and international problems.

In addition to the need for scientific manpower to serve our growing economy is the need for a scientifically literate citizenry which can appreciate science as a humane pursuit. As a result of scientific and technological advances we find ourselves drawing closer, day by day, to an economy and culture that require a high degree of general literacy in the layman. Local school boards, State departments of education, and institutions of higher education are becoming aware of the need for a scientifically literate citizenry with an improved technical vocabulary, conceptual understanding of the scientific enterprise, and a scientific attitude which will assure a wiser and more intelligent voting population.

The chief resources for meeting the needs for specialized expertness in science and general scientific literacy are the classroom teachers in elementary schools, secondary schools, and colleges. Curiosity is the strong and pervasive strand found in the heart of the scientific enterprise and is a necessary component of science teaching and learning. Curiosity is also a common characteristic of young people and one which effective teachers nourish. In the education of all youth in science, nothing is more important than the daily experiences in regular classroom and laboratory teaching. It is here in the classroom, with the teacher at the pivotal point, that our future scientists and scientifically literate citizens are lost or discovered. Our national needs demand improved science teaching.

In addition to formal classroom instruction, a program of class-related activities is needed to stimulate an interest in the student to whom science is new and to satisfy the student who has developed a deep interest and competency in science. This science-oriented student needs a purposeful program of interrelated science activities and classroom and laboratory experiences. Properly designed club-type programs encourage the student to build on the foundation laid in the formal classroom situation. Often they stimulate interest where formal classroom activities have failed. Club participation allows the student to discover new interests in science and to extend his knowledge by following his natural curiosity. Thus club participation feeds back into classroom and laboratory activities and reinforces them.

Extraclass activities such as science clubs and other science youth programs foster student interest by allowing and encouraging individual pursuits which supplement classroom and laboratory experiences. Today's students who have intrinsic interests in science will form the basic scientific manpower pool of the future. The youth organization should seek to strengthen future scientific accomplishments through activities that will identify and use all available resources at the National, State, and local level.

Some of the specific aims and objectives should be—

1. to develop an abiding interest in science, mathematics, and technology on the part of the young people of America;

2. to develop a broad conceptual understanding of science and the scientific enterprise and its contribution to everyday life;
3. to encourage participation in individual research programs that will help the student develop the process of scientific inquiry;
4. to encourage the promotion of exhibitions at which members of the clubs may display their scientific works and projects;
5. to provide an opportunity for the exchange of scientific information and ideas among members of the clubs;
6. to promote and participate in worthwhile programs for the improvement of science instruction at all levels;
7. to develop among youth competent, dynamic leadership in science activities which will develop character and train for responsible citizenship; and
8. to develop among youth an awareness of the satisfactions to be derived from a career devoted to science and technology.

The U.S. Office of Education's interest in science youth activities was deepened by the enactment of Public Law 85–875.

PUBLIC LAW 85–875
85th Congress, H.R. 13191
September 2, 1958

AN ACT

To require the Commissioner of Education to encourage, foster, and assist in the establishment of clubs for boys and girls especially interested in science.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That in order to strengthen future scientific accomplishment in our Nation by assisting in the development of a body of boys and girls with a special interest in science, there is hereby authorized to be appropriated for the fiscal year ending June 30, 1959, and for each fiscal year thereafter, such sums, not in excess of $50,000, as may be necessary to enable the Commissioner of Education to encourage, foster, and assist in the establishment in localities throughout the Nation of clubs which are composed of boys and girls who have an especial interest in science.

Sec. 2. (a) The Commissioner of Education shall carry out his duties under the first section with a view to the ultimate chartering by the Congress of a corporation, similar to the Future Farmers of America, which will seek to—

(1) develop an interest in science on the part of the young people of America,

(2) provide an opportunity for the exchange of scientific information and ideas among members of the clubs,

(3) encourage the promotion of science fairs at which members of the clubs may display their scientific works and projects, and

(4) develop an awareness of the satisfactions to be derived through a career devoted to science.

(b) The Commissioner of Education may utilize any of the personnel and facilities of the Office of Education in carrying out this Act.

Approved September 2, 1958.

Science youth programs and problems differ from State to State and therefore have to be studied and developed on an individual basis. The Office of Education has devoted much time and effort to stimulating the growth of science clubs as an integral part of the secondary school program.

The Office of Education has taken two major steps toward the implementation of the law through (1) science youth congresses and (2) the preparation of a proposed charter for a national science youth organization as called for in Public Law 85–875.

During the fiscal year 1961 the Office of Education contracted with the Massachusetts State Department of Education and the Texas Education Agency for the purpose of conducting science youth congresses which would serve as pilot programs. These programs were cosponsored by the Office of Education and the States, with the Office of Education contributing financial aid for essential costs up to $5,000 the first year, $2,500 the second year, and providing only consultative assistance the third year.

A science youth congress is designed—

1. to enumerate and evaluate science youth activities (these include such activities as science clubs, science fairs, science and mathematics contests, field trips, extraclass conservation programs, and summer science institutes and camps);
2. to provide an oportunity for students to participate in regional and State science fairs, to read their scientific research papers, to hear outstanding scientists discuss current science topics, and to discuss their science club programs, plans, and problems; and
3. to provide an opportunity for science teachers to learn of the benefits that accrue to the student and the school in certain science youth activities, to observe good science education practices, to hear outstanding scientists discuss current topis in science, to meet with science club sponsors and fair directors, and to study and evaluate these activities as they interact with the regular science class and laboratory programs of the school.

The first congresses were held at the University of Massachusetts, Amherst, Mass.; the Wentworth Institute, Boston, Mass.; and Austin and El Paso, Tex. These programs were expanded in fiscal year 1962 to include two new centers in Massachusetts; the addition of the Corpus Christi schools in Texas; and the participation of the third State, Georgia, with congresses in Savannah, Waycross, and Atlanta. Additional States will be invited to participate in fiscal year 1963.

The second major step in the science youth program of the Office of Education is directed toward the implementation of section 2(a) of the law, which reads in part: "The Commissioner of Education shall carry out his duties under the first section with a view to the ultimate chartering by the Congress of a corporation, similar to the Future Farmers of America . . . ."

The Office has worked directly with the leaders of the various science, mathematics and engineering club organizations in developing plans for a national organization with Federal sponsorship. A variety of organizational structures and procedures have been carefully explored to determine which will best serve the purposes of Public Law 85–875 and, at the same time, provide maximum benefits to the potential scientist, his teacher, and the national welfare. The Office of Education is developing proposed legislation as called for in section 2(a) of the law.

Among the membership of the oldest and most famous of science clubs, the Royal Society of London, there were such notables as Davy, Cavendish, Hooke, and Leeuwenhoek. No doubt there are many potential scientists among the membership of our clubs throughout the Nation today. The needs of our Nation cannot be met unless great efforts are made to stimulate, foster and assist this future manpower potential.

PRECEDING PAGE BLANK- NOT FILMED

Reports From Four States:

Emerging Programs in the Improvement of Science Education in Florida

Robert D. Binger

Supervisor of Science Education
State Department of Education, Tallahassee, Fla.

IN ORDER TO CLARIFY the nature of the task involved in the improvement of science education in the State of Florida and the significance of the steps already taken toward this end, I want first to present a few general statements concerning Florida, its educational program and some problems facing its science educators.

1. Florida has a very rapid rate of population growth. Many schools are hard pressed just to provide standard classroom space for all students, let alone the problem of providing specialized facilities.
2. Florida is now undergoing a change from a predominantly agrarian State with an economy greatly dependent upon tourism to one with an economy based upon industry, tourism, military installations, aerospace activities, research centers, and agriculture.
3. The bulk of the population is concentrated in large urban areas such as Miami, and the major part of the school population is found in these areas; but by far the greatest number of individual schools are found in the rural areas. Vast amounts of land are thinly settled or uninhabited, with the result that distances between county seats and school centers are often great.
4. Because of the large number of small schools, many science teachers are required to teach several different subjects. Often one person is the "science department" with the junior high science "farmed out."

5. Florida teacher-training institutions train only one out of every six of our teachers. This puts us in the spot of not having much to say about what type of training these people receive.

6. Many of our sparsely settled rural counties have a very poor tax base with millages already at the established limits. In spite of our fine Minimum Foundation Program, which has done a tremendous job in raising the level of the instructional program, it is still "touch and go" in many systems.

7. However, we have much to be proud of and much upon which to build. For instance, elementary science has been required in the elementary schools since the early 1930's, and each elementary school teacher must take, for certification purposes, a course in the teaching of elementary science. Science is required in grades 1 through 8 and offered in grades 9 through 12. We rank above the national average in course offerings.

8. Our high school seniors have consistently scored above the national average in mathematics and science on the Senior Placement Tests which we require all seniors to take. The median scores currently are near the 70th percentile.

9. We have made great strides in building up our facilities and equipment inventories and in increasing the amount and quality of laboratory experiences our students get, largely because of the NDEA program.

Thus far, as well as we can determine, over 250 teachers have voluntarily elected to take PSSC training. This represents approximately 65 percent of our physics teachers who, in turn, teach about 85 percent of those students taking physics.

As far as evaluation is concerned, a study is now in progress at Florida State University. The results appear to be favorable for PSSC at this point but are not yet in shape for a final analysis.

Chipola Area Education Project—STEPS Program

Another project of which we are quite proud is the STEPS Program, which has been developed under the leadership of the U.S. Office of Education within the Chipola Area Education Project. The CAEP is a cooperative venture on the part of seven counties which are served by Chipola Junior College. It started as a means of establishing a testing and guidance center which the individual counties desired but could not support on an individual basis.

Thus far the following steps have been taken:

1. Area and local advisory committees for teacher and lay groups have been established. A number of meetings have been held to discuss trends in science education, identify problems, and seek ways and means of solving these problems.
2. A self-study was made by all of the schools in each county and the results summarized by county and for the area. Strengths and weaknesses were identified.
3. On the basis of the self-study reports, conference findings and observations by consultants, recommendations were made for short- and long-range plans to improve the science and mathematics programs. The updating and upgrading of teacher training received priority attention in these recommendations.
4. Institutes patterned after the PSSC institutes were held for the CBA and BSCS (Yellow Version) programs. One chemistry teacher from the area was selected to participate in a regional center for the CHEM study program.
5. An elementary science extension course was established and plans made for a CHEM Study extension course.
6. Plans have been laid to enlist the aid of local industry in obtaining funds to hire full-time mathematics and science supervisors.

Because certain of the above conditions require corrective action and because others have established a fertile field for growth, we have instigated a number of programs.

Establishment of the PSSC Program

Through a cooperative arrangement between the State department of education, Florida State University, and a number of the county boards of public instruction, we have been able to provide training for approximately 225 teachers in PSSC Physics through the National Science Foundation-financed institutes. An undetermined number have attended PSSC institutes elsewhere. The institutes set up by Florida State University under the leadership of Dr. Stanley Marshall were unique in that they were a combination of an intensive period of training during August prior to the opening of school and a 3-hour session each week during the school year held in regional centers. Six hours of graduate credit were earned. Fees, books, and travel expenses were provided.

We found that the 2 weeks of intensive training gave the teachers enough of a lead on the students and that the 3-hour sessions each week provided opportunities for the sharing of experiences on an individual and group basis and the straightening of problems which arose before they became too involved.

Our department did much to pave the way in encouraging local school officials to participate in the program, but our main effort was in providing the equipment for each school represented. Our State NDEA plan calls for matching on a statewide basis, and consequently we were able to purchase all of the equipment in one order, once it had been established how many students would be involved. The county boards of public instruction purchased the textbooks, laboratory guides and tests, as well as paid for film rentals.

We are quite pleased with the results of our efforts so far. Laboratory-centered courses are now in schools which formerly had only "read-about, talk-about" science courses. An improvement can be seen in the quality of laboratory experiences in those schools which had laboratory courses prior to the advent of this program. Rather than apathy and indifference on the part of many science teachers, enthusiasm and an eagerness to continue to build the program can be found.

The success of this approach has led us to explore the possibility of establishing a similar project in Central Florida.

Junior High School Institutes

We have held and are currently operating institutes for the improvement of the junior high science program. A 3-year series of institutes, financed through NSF funds, has been completed. This was held in Hillsborough County under the leadership of Dr. N. E. Bingham of the University of Florida and involved both science education and arts and sciences personnel. Courses in mathematics, geology, chemistry, physics, and biology were taught on an off-campus arrangement. The science education phase included, along with methods, the identification of concepts, activities, and resources, which were then consolidated in a scope and sequence guide.

A similar project is being conducted in Brevard County under the leadership of Dr. Stanley Marshall of Florida State University. Dr. Marshall is also currently directing a 3-year series of institutes for the junior high science teachers of Broward County. These institutes are NSF financed and are designed to provide a broad overview of the biological, physical, and earth-space sciences, as well as the mathematics considered important for junior high science. Methods and techniques are presented along with the subject matter.

The Georgia Program in Science Curriculum Revision

H. Victor Bullock

Science Consultant
State Department of Education, Atlanta, Ga.

OUR SCIENCE Curriculum Revision Program dates back to the mid 1950's when a committee from the Teacher Education Council made a study and partial analysis of the adequacy of science instruction in the public schools of Georgia.

The study showed there was a strong indication of the necessity for developing, among other things—

- **a sequential and integrated science curriculum from the 1st through the 12th grades;**
- **practical and workable instruction guides for implementing an articulated curriculum;**
- **a program of science conferences to provide refresher courses for the trained science teacher as well as additional subject matter courses to improve the competency of poorly prepared teachers;**
- **a program designed to help teacher-training institutions in developing sound preservice programs;**
- **a program for science supervision and counseling for inservice teachers;**
- **district conferences throughout the State for the purpose of implementing the science curriculum materials; and**
- **a program for securing the "right kind" of science teachers in the public schools of the State.**

In the summer of 1957 a group of 40 educators, representing all segments of education, came together in a production workshop. This group was directed to write a sequential integrated science curriculum for grades 1 to 12. (I now ask myself, how ridiculous can one be?) This group did write a tentative guide for grades 1 to 8.

During the 1957–58 school year the materials were tried out in some 40 systems over the State. These centers were selected very carefully in terms of administration, supervision, and instruction, together with geographical spread throughout the State. From these pilot schools we obtained much valuable information relative to the value of the materials along with suggestions for improvement. The next step was the refinement of the materials by an editing committee.

Guides were developed for physical science and biology during the summer of 1958.

In early 1958 the State department of education added a person to the staff whose duties included the undertaking of the necessary steps to revamp science education in the State according to the broad outline suggested by the Teacher Education Committee.

Realizing the immensity of our proposed program and the utter impossibility of one person's giving adequate leadership from the State level, the State board of education agreed to supplement the leadership functions by adding five area science consultants to serve the various areas of the State. Five outstanding science teachers were selected to train at Oak Ridge under the Traveling Teacher Program sponsored by the National Science Foundation and the Atomic Energy Commission.

The equipment and materials carried by these traveling teachers were provided by the National Science Foundation, the Atomic Energy Commission, and the State department of education. During the first half year of operation they concentrated their efforts in working with high school teachers and their science and mathematics classes.

We recognized the problem of implementing the science guides and decided that our first order of business was to orient some 20,000 teachers in making use of them. Scores of meetings were held over the State to familiarize educators with our plans. The 200 State-paid directors of curriculum who serve in local school systems served as a nucleus from which information was disseminated.

Dozens of 1- and 2-week workshops have been conducted during the summer months by the traveling teachers to help local teachers gain a better understanding of what we are trying to do. These workshops run 6 hours per day. There are no fees and no credit—just hard work.

During the regular school year the traveling teachers work in classroom situations with teachers at both the elementary and secondary levels. A traveling teacher may work in a third-grade situation 1 hour and then give a lecture-demonstration on space travel to a high school physics class the next hour.

An abbreviated 4-year report (see following table) gives some idea of our scope of operation. Normally we are able to service only about one-fourth of the requests we receive for the traveling teachers.

The problem of getting and retaining that "right kind" of teacher for our science program has been most difficult. In order to maintain a staff of five, it has been necessary to train nine persons.

Selected figures[1] concerning the Georgia traveling science teacher program: October 1958–June 1962

Year	Number of schools visited	Number of student hours spent in lecture-demonstrations	Number of miles traveled	Amount of expenses for vehicles
1958–59	127	143, 056	61, 005	$1, 191
1959–60	130	146, 649	79, 906	2, 322
1960–61	196	103, 700	70, 538	2, 286
1961–62	295	140, 102	72, 262	2, 468
Total	748	533, 507	283, 711	8, 267

[1] Table does not reflect time spent in:
Talks to Service clubs; PTA; Science clubs; Local Georgia Education Association meetings.
Saturday meetings of various kinds.
Orientation of teachers in use of science curriculum materials.

In order to improve teacher competency in science, we have used several inducements, one of which is a grant-in-aid program. Under this program, teachers are reimbursed up to $450 for attending summer school and taking content courses. In the beginning this was limited to teachers of science, mathematics, and foreign languages, but has now been expanded to take in almost all disciplines. Many teachers are using this means to gain the sixth-year certification for which a State bonus of $100 is added to the salary schedule.

Georgia has plans for a State educational TV network. Two stations are on the air and two more will be operational by January 1963. One function of these stations is to provide inservice education.

Dr. W. B. Baker, Emory University, through a grant from the National Science Foundation, has developed a series of telecasts on using the science guides. Consultants from his staff meet with groups of teachers every fourth Saturday in workshop situations to aid teachers in their day-to-day efforts. This program will be expanded as other stations become operational.

Missouri's Inservice Science Workshop Program

John B. Leake

Science Consultant
State Department of Education, Jefferson City, Mo.

SINCE the National Science Foundation had already embarked on several programs for the improvement of science at the secondary level prior to the signing into law of the National Defense Education Act, we felt, at the inception of our consultative program, that our greatest effort should be aimed at the evaluation and improvement of the elementary and junior high school programs. During the school year 1960–61, our major occupation in the inservice science workshop area was for the elementary school teacher. In this same period we held one workshop for secondary school science teachers. Since that year we have continued both programs.

Elementary School Science Program

Our objectives for the elementary school workshops are—

- ◆ to provide teachers with the opportunities to raise their level of understanding and to lay the foundation for further self-improvement;
- ◆ to create such an atmosphere of enthusiasm for science that teachers and students alike may enjoy the pursuit of its excellence;
- ◆ to illustrate an intuitive approach with the assistance of teaching aids, experimentation, and simple apparatus;
- ◆ to provide experiences and materials whereby teachers may broaden their horizons relative to experimental programs, pertinent literature, and extracurricular activities in the field of science; and
- ◆ to structure a science program for the first 8 years of school.

In short, we are trying to give our participant teachers enough science background for further reading, an enthusiasm to overcome the fears of science and laboratory work, and a directional structure for the K to 8 program.

Typically, a school district site is selected and the administrator is contacted to ascertain his willingness to have his school used for a meeting place. If he replies favorably, he is asked to provide facilities for a 2-hour meeting 1 night per week for the 10 weeks of the workshop. In addition, he is asked to invite seven nearby school districts each to send four key teachers to the workshop, the host school being allowed five. This results in a class of 33 teachers and a class-hour commitment of 20 hours.

Each State consultant may run as many as three workshops per week and two series per year. They also do demonstration teaching in the participating school systems and provide other consultative services typical of the NDEA program.

The intent of the workshops is to develop basic ideas that lead into understandings of more and more complex ideas. Topics included in each workshop include—

- measurement (time, distance and mass)—an investigation of methods for measuring magnitudes and how they are being improved;
- mechanical energy—a development of mechanics for the exploration of the interrelationship of all energy;
- heat—evidence of energy of motion;
- energy and the electromagnetic spectrum—radiant energy can be systematized in a continuous spectrum;
- atoms and elements—a discussion of the building blocks of nature;
- matter and its composition;
- nuclear energy and radioactivity;
- basis of life—chemical organization of living material;
- energy requirements of living systems—source and exchange of energy for life; and
- hereditary control of living organisms.

As most programs develop they change, and this one is no exception. Although basic aspects of the above outline are retained, a departure into classroom sequence is made, based on such topics as the atom. electromagnetism, mechanics, light, and life.

It is hoped that during the course of the workshop the participants will develop an approach to classwork which will elicit curiosity, imagination, discovery and thoughtfulness on the part of their pupils. This, after all, is our goal in the teaching of science in the elementary school.

At the present time, and in the foreseeable future, only the *UNESCO Sourcebook of Science* is recommended as text material. All participants, however, are urged to subscribe to *The Elementary School Science Bulletin* and *Science Newsletter*. Supplementary reading lists are also distributed.

Strong encouragement is given principals and superintendents to use their participating teachers in helping to educate other teachers in the individual school systems to improve their science offerings.

Several types of evaluation have been attempted. One is an immediate critique, which is used to alter the program so as to meet more nearly the felt needs of the participants. Another is a questionnaire sent some months later to former participating teachers to ascertain to what degree their classroom presentations have been influenced. Both of these devices have met with mechanical success, but it has been difficult to determine if they are sufficiently objective to be meaningful.

Secondary School Science Program

The present secondary school workshop is titled "Radiation Topics for Science Teachers." The mechanics of setting up the workshop are very similar to those of the elementary school program. One of the general purposes of this inservice program is to acquaint teachers with basic concepts of the natural sciences as they relate to radiation biology. Emphasis is on the important interrelationships between the various sciences.

Participants are afforded the opportunity to obtain some practical experience in handling radioactive materials and nuclear measuring devices. The use of inexpensive teacher-constructed equipment receives some emphasis. By working with radioisotopes, teachers gain confidence in experimenting in this area and become familiar with the necessary safety procedures incident to handling materials that demonstrate alpha, beta, and gamma emission.

Another purpose of this inservice training program is to provide each teacher with a broader contemporary scientific knowledge and to increase his abilities in motivating students to continue their education in science. To this end the program encourages teachers to incorporate radiation experiments into their curriculums so as to stimulate in senior high students an appreciation and understanding of nuclear energy.

Evaluative Workshops

An effort which we are contemplating is an evaluative workshop for a K to 12 science program. One pilot session has been run along these lines. In this workshop we hope to involve administrators and key teachers from about five school districts in a thorough evaluation of their programs. One goal will be to arrive at a stepwise sequence, individually tailored for each school system, for the implementation of a modern K to 12 program.

Here again the mechanics of setting up the workshop will be similar to those of the other programs. Of the three workshops, we feel this evaluation type will have a far greater effect than either of the others.

The Pennsylvania Science Program

Albert F. Eiss

Science Education Specialist
State Department of Public Instruction
Harrisburg, Pa.

IN DISCUSSING the duties and responsibilities of science specialists with the representatives of the various States, one notices the great differences in organization that exist among them. This means that a successful program in one State may not be desirable in another. However, many ideas may be helpful, even though the overall plan may not be adaptable.

Organization of the Program

Our Division of Mathematics and Science consists of a coordinator, two mathematics specialists, and three science specialists. It is a part of the Bureau of General and Academic Education in the Department of Public Instruction. Two science specialists are working full time on curriculum improvement and development. At the present time the Department of Public Instruction is sponsoring a Curriculum Improvement Program. The science phase of this program is in its second year of development.

Plans for improving the science curriculum got underway in October 1960, when the first of the State Science Curriculum Committees convened. These committees were somewhat unique in their organization and membership. They were composed of research scientists, university and college science teachers, administrators, supervisors, public school teachers at all levels, members of the U.S. Office of Education, a psychologist, and a layman. Committee members were not selected for their reputation or seniority; rather, they were almost handpicked for their interest in science education and their understanding of what constitutes good science teaching. With such a varied group, public school teachers were distinctly in the minority. To assure that the majority vote of a committee would not override the decisions of a more experienced minority, all committee decisions were made on the basis of unanimous agreement. Because the groups were carefully selected and understood the problems of science education, they reached agreement in a surprisingly short period of time.

The committees did not "rubberstamp" department ideas. In fact, some of the committee decisions were a cause of concern for some of the State specialists.

Curriculum Improvement Program

Two decisions were reached by the committees early in their deliberations: that we would work on the development of a K to 12 curriculum (later this was extended to K to 16 and now includes adult education), and that curriculum planning should begin with the elementary school, then continue with the higher grades.

Several new publications have been produced. These have been related to the K to 9 curriculum, which has been neglected in many areas of the country. The publications are grouped in a series called *Science in Action.* At present, 3 booklets have been produced and used experimentally in about 200 schools in the State; 3 more are now in press.

The main characteristics of the *Science in Action* series are: the material is a guide for teachers, not a course of study; the material uses the experimental approach for teaching science; measurement in both metric and English units is emphasized at all levels, beginning with the kindergarten; and great emphasis is being placed on teaching students to think and reason.

Other Activities

Science specialists are working closely with various scientific and professional organizations. The U.S. Office of Education, the Pennsylvania Academy of Science, the Pennsylvania Science Teachers Association, and the National Association for Research in Science Teaching have been among the sources of mutual help and assistance that have been beneficial to all groups.

The department works closely with industrial and commercial interests as well. For example, the Pennsylvania State Chamber of Commerce and several business organizations have donated funds through the academy for carrying out part of the initial development of the *Science in Action* program.

Science specialists are responsible for the approval and evaluation of NDEA projects. They are also working to develop suggested equipment lists for college science laboratories, to suggest standards for high school science laboratories, and to suggest criteria for evaluating the effectiveness of science teachers.

Routine problems are not lacking. In addition to the usual routines of officework, specialists are sometimes asked to visit schools as members of evaluation teams, visit colleges to study their science programs, work for the improvement of teacher education, and assist in planning programs of inservice education.

Future Goals

The curriculum improvement program is in its second year. We are working on a four-step program: (1) organization of committees for setting goals and objectives; (2) preparation of guides to action; (3) implementing and selling the program; and (4) continuing revision of the program. We are now well along on the second step and are beginning the third. We do not anticipate that the fourth—the continuing revision of the program—will ever be completed.

Our goal is to sell the program to teachers and administrators. We do not plan to mandate a curriculum. This makes the public relations aspect of the program very important. To date we have been most fortunate in our good relations with the science teachers association and the State academy, as well as with administrators and college personnel. Our aim is to continue this good relationship.

We intend to develop test questions for all levels of instruction and at all grade levels. We plan to work for the improvement of science laboratory work, particularly in the development and use of open-ended experiments. We hope to strengthen our ties with the Pennsylvania Science Teachers Association and the Pennsylvania Academy of Science, and to offer our assistance to other professional groups in any way possible. (For example, we are acting as a clearinghouse for information relating to various science organizations.) We have encouraged the organization of the Capital Area Professional, Engineering, and Scientific Society and have acted as an intermediary between this group and schools and teachers requesting assistance or advice.

Conclusions

We have found that communication is an almost universal problem. This is serious at all levels and in all groups. We have decided that good public relations are essential to the smooth functioning of our program as it is planned.

The *Science in Action* program is still experimental, but we have seen some very encouraging results. We are working closely with a suburban Harrisburg school, where the teachers [illegible] us to visit classes and sometimes even to teach. We have seen kindergarten children using the metric system, a second-grade class using a platform balance for solving algebraic equations, a third-grade group using linear slide rules, and special education students so interested in science that the teacher had to insist that they go home when school was over.

Of one thing we are very certain: we had been failing to challenge our students. We have found that first-grade students can discuss gravity—in fact, we found they were already acquainted with the term from watching TV. Fourth-grade students can discuss weightlessness in space as intelligently as some college students. And junior high school students can ask intelligent questions that will amaze even a research scientist.

In fact, one of the conclusions we have reached is that the quality of the science program is usually not limited by the students' ability; rather it is often the teachers' limitations that define the level at which the program must proceed. We have learned enough to know that at present we cannot define the limits to which the science program can develop.

Appendixes

PRECEDING PAGE BLANK-NOT FILMED

APPENDIX A

Guidelines for the State Supervisor of Science

In keeping with one of the objectives of the conference (". . . to develop guidelines for leadership in supervision of science"), small group roundtable discussions were held for the purposes of identifying the problems and responsibilities of the State supervisor of science. Initial groups were organized on the basis of similarity of situations in the States represented. As problems emerged and were refined into six areas, each conferee selected the area of his main interest for further discussion and guideline development.

Guidelines were developed in the areas of professional and public relations, preservice and inservice education, curriculum, facilities and equipment, research, and the nature of science. Although these guidelines are intended to have a general applicability, it is recognized that their utility may be limited in specific situations. The guidelines follow:

Professional and Public Relations

What is the leadership role of the State supervisor of science in interpreting science and science education programs to school officials and to the lay public?

The leadership role of the State supervisor of science is to—

- ◆ Encourage State and local school officials to formulate functional, realistic statements of the philosophy, purposes, and objectives of science education at all levels of the public schools.
- ◆ Assist school administrators, civic groups, and laymen in understanding the need for improvement in science education and the importance of their role in supporting it.
- ◆ Provide and interpret information concerning the status of science education within the State and foster unified action by local administrators and supervisors of science, civic groups, and laymen for purposes of understanding and improvement.

- Establish close liaison with scientific and technical organizations and enlist their aid in the improvement of science education.
- Create a climate of public understanding in which improvements in science education are possible.

Preservice and Inservice Education

What is the leadership role of the State supervisor of science in bringing about and evaluating realistic preservice and inservice teacher education programs to meet the demand of quality education in science?

The leadership role of the State supervisor of science for preservice education is to—

- Cooperate with institutions of higher learning to plan appropriate programs in the sciences as a part of every teacher's undergraduate education, regardless of specialty or of level of instruction.
- Cooperate with institutions of higher learning, certification and accreditation agencies to assure that graduating teachers are adequately prepared to teach both traditional and newly developed courses of study in their specialties.
- Work with institutions of higher learning to assure that graduating teachers are thoroughly prepared to teach the processes of scientific inquiry and the history and philosophy of science.

The leadership role of the State supervisor of science for inservice education is to—

- Encourage and aid local school districts in evaluating the need for and in organizing and conducting programs of inservice education.
- Assist local school districts to obtain consultants and other resource persons to staff inservice programs.
- Cooperate with institutions of higher learning in the developing of quality institutes for teachers of science.
- Disseminate information regarding institutes and vigorously encourage teacher participation therein.
- Encourage local school systems to make effective use of the competences of teachers who have attended institutes.
- Encourage teacher participation in professional associations and activities.
- Recognize and make known the obligation of every teacher to a lifetime of continued learning.

Curriculum

What is the leadership role of the State supervisor of science in the planning, development, and evaluation of science curriculums to meet the needs of quality education in science?

The leadership role of the State supervisor of science is to—

- Disseminate information about new curriculum materials at all levels and in all fields of science, and encourage their use where appropriate.
- Apprise State officials and local school systems of existing deterrents to program improvement and provide assistance in their alleviation.
- Encourage and assist in continuing evaluations of science programs at the local level.
- Provide groups responsible for curriculum improvement with guidelines for developing a sequential science program appropriate for all pupils.
- Promote both individual and group action at all levels for the improvement of the science program.
- Emphasize the importance of and advocate adequate time for appropriate laboratory experiences in science.

Facilities and Equipment

What is the leadership role of the State supervisor of science in the planning and development of facilities and equipment to provide for quality education in science?

The leadership role of the State supervisor of science is to—

- Assist responsible local officials in drawing up specifications for new school buildings and science facilities which will implement the official philosophy and objectives in the science curriculum.
- Work with local school personnel, architects, and cognizant agencies in the planning of school science facilities which are adequate with respect to space, location, design, services, storage, and safety.
- Work with responsible local school officials to plan for adequate science budget provisions for furniture, equipment, and instructional materials in new buildings and for annual operation of the school science program.
- Assist local school personnel in establishing effective quantitative and qualitative standards for the selection and procure-

ment of appropriate equipment and instructional materials for science.

- Work with local school systems to ensure the most effective uses of science equipment.

Research

What is the leadership role of the State supervisor of science in stimulating, conducting, and interpreting research in science education?

The leadership role of the State supervisor of science is to—

- Identify those schools and personnel in his State willing to participate in experimental studies and encourage their cooperation in such studies.
- Assist local school systems and, where appropriate, individual teachers in the design and conduct of carefully defined research studies.
- Coordinate experimental studies and pilot programs among schools within his State.
- Maintain an up-to-date record of the progress and results of science education research conducted within his State.
- Maintain liaison and encourage cooperative efforts with universities, colleges, and other centers of science education research within his State.
- Disseminate and interpret by means of newsletters, periodicals, forums, and speeches the results of valid science education research to the science teachers in his State and encourage their use of these results.
- Transmit the results of significant research in his State to the association of State science supervisors and the U.S. Office of Education.
- Maintain, through the association of State science supervisors, liaison with national organizations conducting and reporting research in science education.

Nature of Science

What is the leadership role of the State supervisor of science in bringing about greater sensitivity to the spirit and nature of science?

The leadership role of the State supervisor of science is to –

- Providing liaison with appropriate groups and agencies for science teachers to observe the processes of scientific inquiry as illustrated in films, demonstrations, educational television programs, and research in progress.

◆ Guide the science teachers of his State in the meaning and use of open-ended student investigations.

◆ Encourage the science teachers of his State to engage in their own programs of scientific research.

◆ Encourage teachers and students to examine the writings and work of great scientists, that they may learn to recognize and appreciate those traits which are characteristic of the true nature of science.

APPENDIX B

Participants in the Conference

F. K. Alexander,
Administrator, Title III, NDEA
State Department of Education
Lincoln, Nebr.

Uhlman S. Alexander
Research Assistant for Science
U.S. Office of Education
Washington 25, D.C.

Eric R. Baber
Acting Assistant Commissioner
Division of Elementary and Secondary Education
U.S. Office of Education
Washington 25, D.C.

J. Darrell Barnard
Department of Science and Mathematics Education
New York University
New York 3, N.Y.

Albert L. Berry
Science Supervisor
State Department of Education
Frankfort, Ky.

Robert D. Binger
Supervisor of Science Education
State Department of Education
Tallahassee, Fla.

Paul E. Blackwood
Specialist for Science
U.S. Office of Education
Washington 25, D.C.

Glenn O. Blough
Professor of Education
University of Maryland
College Park, Md.

Herman R. Branson
Department of Physics
Howard University
Washington 1, D.C.

T. C. Bruce
Science Supervisor
State Department of Education
Columbia, S.C.

H. Victor Bullock
Science Consultant
State Department of Education
Atlanta, Ga.

James W. Busch
Supervisor of Science
State Department of Public Instruction
Madison, Wis.

Lewis H. Caldwell
Consultant in Science and Mathematics
State Department of Public Instruction
Topeka, Kans.

Chauncey B. Coor
Director of Secondary Education
State Department of Public Instruction
Phoenix, Ariz.

Watson Davis
Director, Science Service, Inc.
Washington 6, D.C.

Bowen C. Dees
Assistant Director for Scientific Personnel and Education
National Science Foundation
Washington 25, D.C.

K. L. Dooley
Director of State-Federal Relations
State Department of Public Instruction
Bismarck, N. Dak.

Emery S. Dunfee
Science Supervisor
State Department of Education
Augusta, Maine

Albert F. Eiss
Science Education Specialist
State Department of Public Instruction
Harrisburg, Pa.

William G. Elliott
Science Consultant
State Department of Public Instruction
Pierre, S. Dak.

E. Glenn Featherston
Acting Deputy Associate Commissioner for Educational Research and Development
U.S. Office of Education
Washington 25, D.C.

William C. Foil
Supervisor of Science Education
State Department of Public Instruction
Raleigh, N.C.

Stanley Fox
Science Consultant
State Department of Education
Columbus, Ohio

James Garner
Supervisor of Science
State Department of Public Instruction
Olympia, Wash.

James A. Garvey
Supervisor in Science
State Department of Education
Providence, R.I.

H. Bentley Glass
Department of Biology
Johns Hopkins University
Baltimore, Md.

Severo Gomez
Science Consultant
Texas Education Agency
Austin, Tex.

Robert D. Graham
Science Consultant
State Department of Education
Carson City, Nev.

William J. Gruver
Specialist for Science
U.S. Office of Education
Washington 25, D.C.

William Guthrie
Assistant in Science and Mathematics
State Department of Education
Trenton, N.J.

Carl F. Hansen
Superintendent of Schools
District of Columbia Public Schools
Washington 9, D.C.

Richard M. Harbeck
Specialist for Science
U.S. Office of Education
Washington 25, D.C.

Edward J. Hart
Supervisor of Science
State Department of Public Instruction
Dover, Del.

Zaboj V. Harvalik
Director, Basic Research Group
Fort Belvoir, Va

Father Francis J. Heyden, S.J.
Professor of Astronomy
Georgetown University
Washington 7, D.C.

J. Dan Hull
Director, Instructional Programs Branch
U.S. Office of Education
Washington 25, D.C.

Lloyd K. Johnson
Specialist for Science
U.S. Office of Education
Washington 25, D.C.

Philip G. Johnson
Chairman, Science Education Division
Cornell University
Ithaca, N.Y.

Thelma N. Johnson
Elementary Science Department
District of Columbia Public Schools
Washington 9, D.C.

Frances D. Jones
Consultant, High School Science
State Department of Education
Montgomery, Ala.

Ralph E. Keirstead
Consultant in Science
State Department of Education
Hartford, Conn.

Stanley E. Kerr
Science Supervisor
State Department of Public Instruction
Des Moines, Iowa

Franklin D. Kizer
Supervisor of Science
State Board of Education
Richmond, Va.

Paul Klinge
Assistant Professor of Education
University of Indiana
Bloomington, Ind.

Dean M. Laux
Consultant in Science and Mathematics
State Department of Education
Trenton, N.J.

John B. Leake
Science Consultant
State Department of Education
Jefferson City, Mo.

Ralph W. Lefler
Visiting Staff Consultant
American Institute of Physics
New York 17, N.Y.

Curtis C. Love
Supervisor of Science Instruction
State Department of Education
Little Rock, Ark.

John R. Ludington
Acting Deputy Associate Commissioner
Bureau of Educational Assistance Programs
U.S. Office of Education
Washington 25, D.C.

Robert G. MacGregor
Associate in Science Education
State Department of Education
Albany, N.Y.

L. Frank Mann
Consultant in Secondary Education
State Department of Education
Sacramento, Calif.

Leo W. Marshall
Science Supervisor
State Department of Public Instruction
Indianapolis, Ind.

Teruo Masatsugu
Program Specialist for Science
State Department of Education
Honolulu, Hawaii

George K. McBane
Director of Science
State Department of Education
Santa Fe, N. Mex.

Howard McCollum
Supervisor of Science
State Department of Education
Baton Rouge, La.

Margaret J. McKibben
Assistant Specialist for Science
U.S. Office of Education
Washington 25, D.C.

Sterling M. McMurrin
Commissioner of Education
U.S. Office of Education
Washington 25, D.C.

D. Gairdner Moment
Chairman, Committee on Education
American Institute of Biological Sciences
Washington 6, D.C.

William E. Morrell
Director, Summer Institutes Program
National Science Foundation
Washington 25, D.C.

Ellsworth S. Obourn
Specialist for Science
U.S. Office of Education
Washington 25, D.C.

John W. Packard
Senior Supervisor of Science
State Department of Education
Boston, Mass.

Richard S. Peterson
Supervisor of Science
State Department of Public Instruction
Salt Lake City, Utah

James H. Pfau
Science Consultant
Box 105
Coco Solo, C.Z.

Albert Piltz
Specialist for Science
U.S. Office of Education
Washington 25, D.C.

Harold Pluimer
Science Consultant
State Department of Education
St. Paul, Minn.

Wayne O. Reed
Deputy Commissioner of Education
U.S. Office of Education
Washington 25, D.C.

R. C. Roberts
Supervisor of Science
State Department of Education
Jackson, Miss.

Maria A. Ruiz
Director of Science Program
Department of Education
Hato Rey, P.R.

Stanley Rutenberg
National Academy of Sciences
National Research Council
Washington 25, D.C.

A. Neal Shedd
Specialist for Science Youth Activities
U.S. Office of Education
Washington 25, D.C.

Robert L. Silber
Educational Secretary
American Chemical Society
Washington 6, D.C.

Benjamin Simmons
Director of Curriculum
State Department of Education
Salem, Oreg.

William L. Smallwood
Supervisor of Mathematics and Science
State Department of Education
Boise, Idaho

B. R. Stannerson
Deputy Executive Secretary
American Chemical Society
Washington 6, D.C.

Robert C. Stephenson
Executive Director, American Geological Institute
Washington 25, D.C.

Bob R. Sternberg
Consultant, Title III, NDEA
State Department of Public Instruction
Lansing, Mich.

Donald B. Stone
Instructor of Earth Science
Mont Pleasant High School
Schenectady, N.Y.

Joseph A. Struthers
Consultant, Science and Mathematics
State Department of Education
Denver, Colo.

Evan A. Sweetser
Consultant in Mathematics and Science
State Department of Education
Montpelier, Vt.

Robert L. Thomas
Supervisor of Science and Mathematics
State Department of Education
Juneau, Alaska

Floyd Thompson
Director of Instruction
State Department of Education
Oklahoma City, Okla.

M. H. Trytten
Director, Office of Scientific Personnel
National Academy of Sciences-National Research Council
Washington 25, D.C.

Howard I. Wagner
Director, Science Education
State Department of Education
Concord, N.H.

Harry M. Watkins
Elementary Science Supervisor
State Department of Education
Frankfort, Ky.

Lewin A. Wheat
Supervisor of High School, Science and Mathematics
State Department of Education
Baltimore, Md.

Lee E. Wickline
Science Specialist
State Department of Education
Charleston, W. Va.

Jerome B. Wiesner
Special Assistant to the President for Science and Technology
Acting Director of the Office of Science and Technology
Washington 25, D.C.

J. Donald Wood
Supervisor of Science
State Department of Education
Nashville, Tenn.

John H. Woodburn
Instructor, Walter Johnson High School
Bethesda, Md.

Archie Woodrome
Science Consultant
State Department of Public Instruction
Springfield. Ill.

○